BIOLOGICAL RESOURCES OF THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

AQUATIC RESOURCES

PAST TRENDS AND PRESENT STATUS OF SELECTED FISH AND INVERTEBRATE SPECIES OF THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

PAST TRENDS AND PRESENT STATUS OF SELECTED FISH AND INVERTEBRATE SPECIES OF THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Prepared for the

Bay-Delta Oversight Council

by

CALIFORNIA DEPARTMENT OF FISH AND GAME

BAY-DELTA AND SPECIAL WATER PROJECTS DIVISION

STOCKTON, CALIFORNIA

September 1993

TABLE OF CONTENTS

Figures

Figures (Continued)

Tables

SUMMARY AND CONCLUSION

This report presents evidence that many aquatic species living in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary have recently experienced serious population declines. Data and trends for phytoplankton, zooplankton, white catfish, Delta smelt, longfin smelt, Sacramento splittail, sturgeon, starry flounder, shrimp, striped bass, and chinook salmon are included, as they are generally recognized indicator species representing broader trends mirrored in other Estuary status reports. Three figures from the report "Status and Trends Report on Aquatic Resources in the San Francisco Estuary" by Bruce Herbold, Alan Jasby and Peter Moyle, vividly illustrate these declines (Figures 1, 2 and 3).

INTRODUCTION

The San Francisco Bay/Sacramento-San Joaquin Delta Estuary (hereinafter "Estuary") is the largest estuary on the west coasts of North and South America. Freshwater runoff from 40 percent of California's land area mixes with Pacific Ocean water in the Estuary, creating highly dynamic and complex environmental conditions which have historically supported a diverse and productive ecosystem.

The upper part of the Estuary, known as the Sacramento-San Joaquin Delta, is comprised of 1,153 square miles of waterways, marshes, farm, and urban land, while the downstream portion is made up of the 478 square mile San Francisco Bay. The Estuary supports many important economic activities; including sport and commercial fishing (including the commercial bait fishery and the party boat recreational fishery), tourism, recreation, shipping, industry and agriculture.

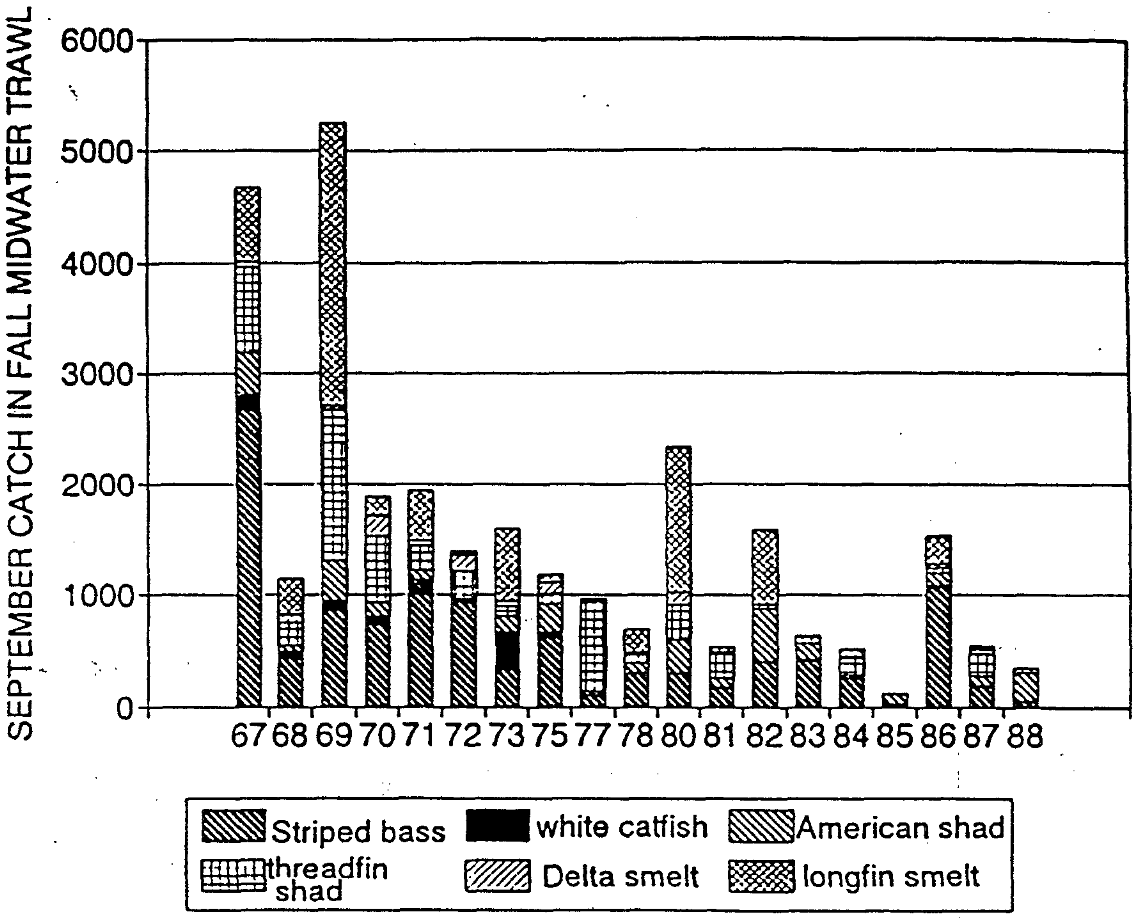


Figure ↑ Catch of six most abundant species during September by the fall midwater trawl survey 1967-1988.

(Figure from Herbold et al, 1992)

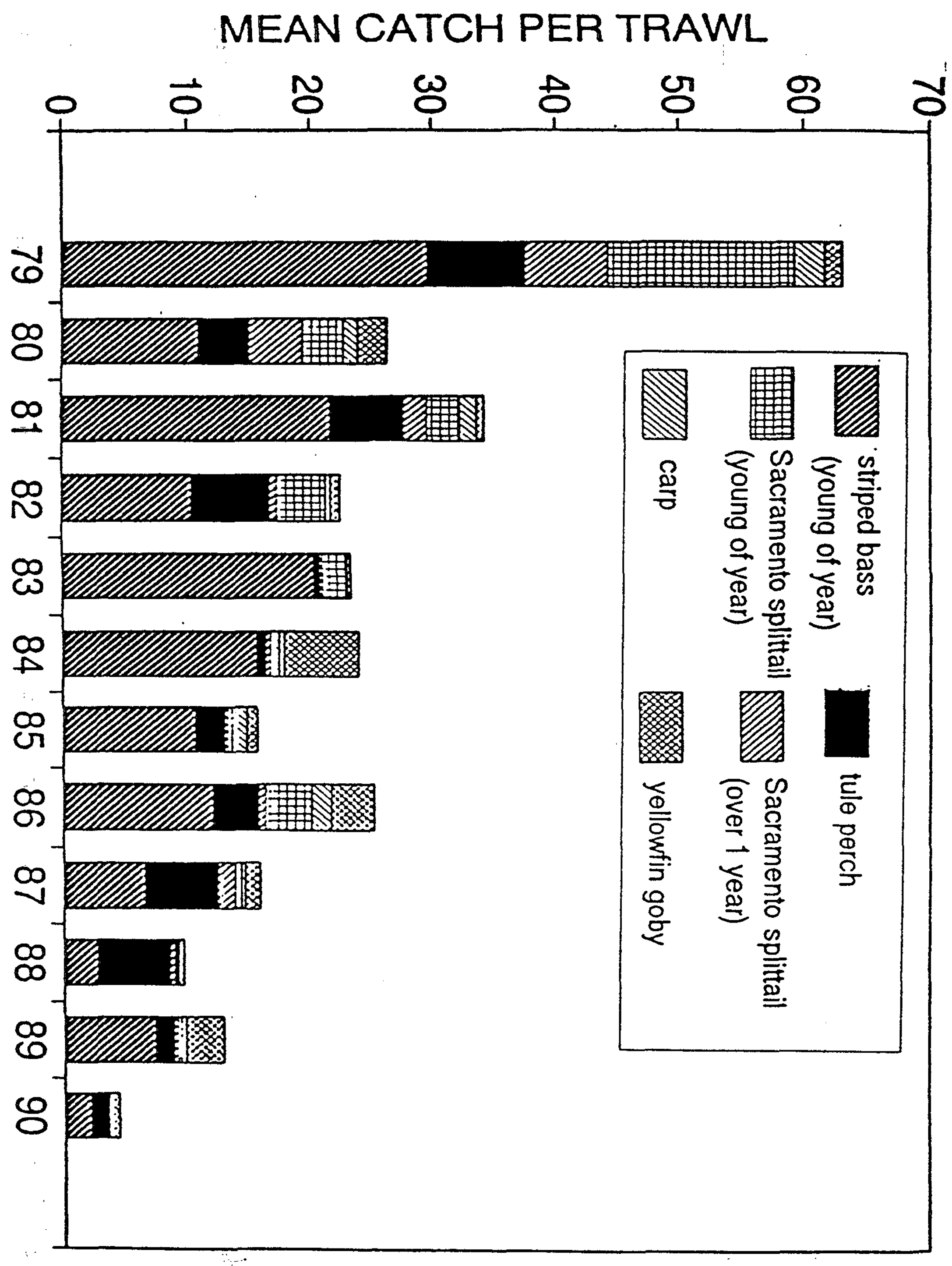


Figure 2 Abundance of six most frequently captured species collected by otter trawl sampling program by UCD in Suisun Marsh.

(Figure from Herbold et al, 1992)

B-000302

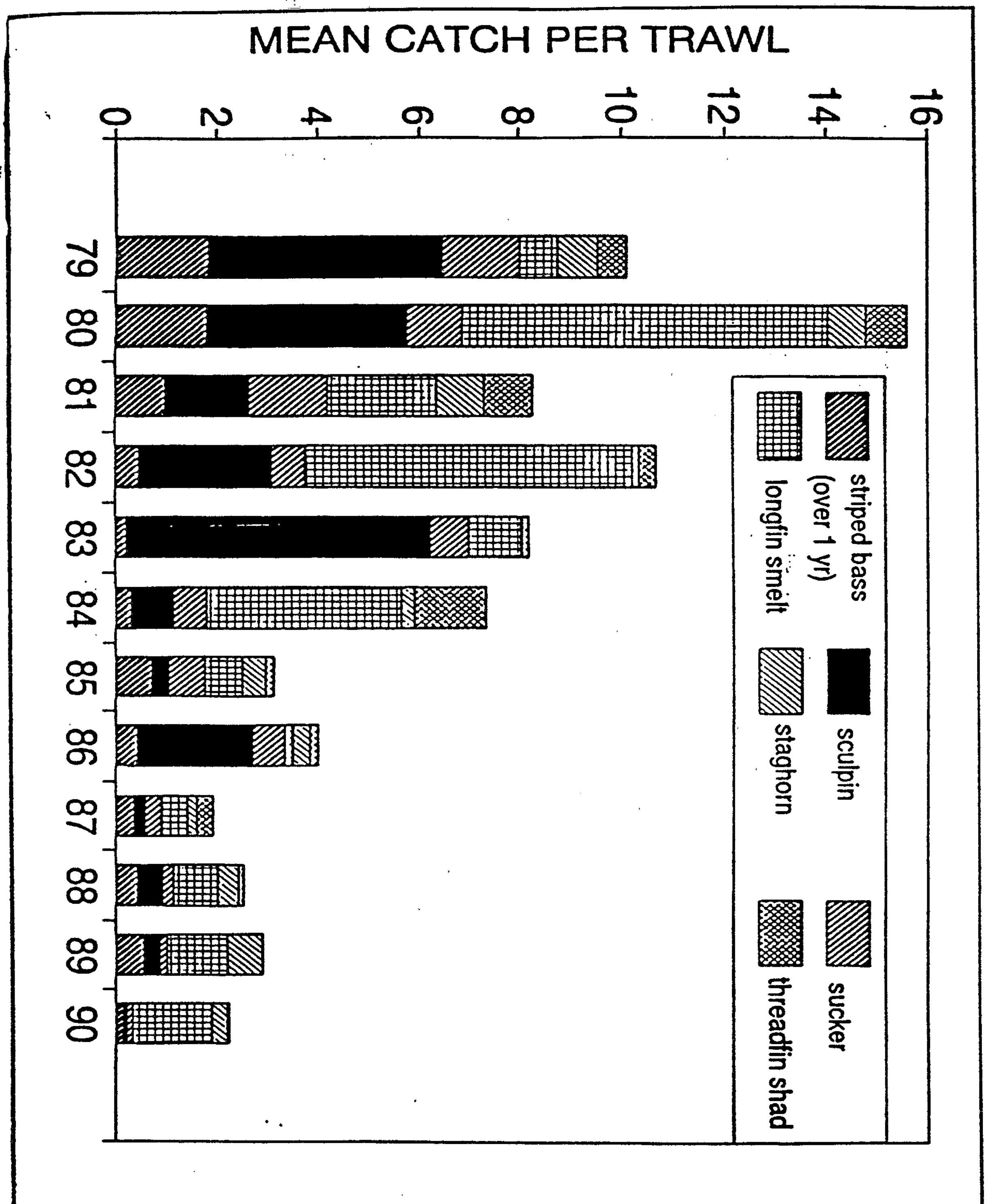


Figure 3 Seventh through twelfth most frequently captured species in sampling of UCD in Suisun Marsh.

(Figure from Herbold et al, 1992)

The Estuary was essentially undisturbed by man until the mid-1800's, when human impact and development began to intensify. Gold Rush-related activities initiated physical, chemical, and biological changes in the estuarine system that would eventually lead to it being highly modified by human activity.

The Estuary's biological resources, particularly, have experienced a major transformation over the last century and a half. Aquatic communities; including phytoplankton (small, floating plants which transform sunlight to food), zooplankton (small animals that feed on phytoplankton and detritus), bottom-dwellers (benthos), and fish have undergone extensive change. Many species of non-native aquatic invertebrates; including clams, oysters, and worms have been introduced into the Estuary in the past century. In addition, more than 50 fish species that occupy the Delta are not indigenous.

The Estuary's ability to maintain consistent levels of abundant species has also been altered over the years. Since the early 1970's, and especially since the 1976-1977 drought, zooplankton and phytoplankton abundance have generally declined in San Pablo and Suisun Bays. Many fish species dependent on the Estuary for food, nursery habitat, and as a migration corridor are in decline too: the spring-run chinook is down 80 percent, while fall-run is down 50 percent; the striped bass population has declined by 70%; starry flounder and Bay shrimp populations have declined; listings under endangered species laws for the spring-run salmon and green sturgeon are actively being considered, and petitions for longfin smelt and Sacramento splittail have recently been filed. In the past, species such as the thicktail chub have become extinct in the system.

It should be recognized that the depleted abundance of most, if not all, of these organisms mentioned above were undoubtedly intensified by the recent drought. The drought also restricted the geographic distribution of some species in the estuary. The low flows which occurred in the last 5 or 6 years are unprecedented in the historical record. Still, it remains to be seen what the long-term, biological consequences of the drought will be.

STATUS AND TRENDS OF SELECTED ESTUARINE SPECIES: A SUMMARY

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton are very small, usually microscopic, single-celled members of the group of simple plants called algae. There are many phytoplankton species in the Estuary and most occur in three general groups: diatoms, dinoflagellates, and cryptomonads. Since these organisms convert the energy of sunlight to food, they are important to the growth or productivity of other organisms as the fundamental building block of the food chain. Clams, worms, mussels and small zooplankton (aquatic animals) like protozoans, rotifers, copepods or cladocerans, feed on phytoplankton.

Phytoplankton abundance is estimated by direct counts of individual organisms or by measuring the amount of pigment (chlorophyll) they produce. Chlorophyll levels (i.e. phytoplankton abundance) have declined in Suisun Bay over the last 20 years (Figure 4). Further, in that same time frame, a previously less common phytoplankton species, Melosira granulata, has dominated most phytoplankton blooms. This composition change is significant because this particular species is not a preferred food source of zooplankton.

There are three important zooplankton groups; rotifers, cladocera, and copepods. From 1972 to 1979 the rotifer populations in the San Joaquin River system have declined to less than a tenth of their originally measured densities (Figure 5). Average densities of cladocerans have similarly shown a long-term decline in abundance (Figure 6). Finally, native copepods have suffered large population declines while non-native species have increased their numbers (Figure 7). Neomysis mercedis (an important bass food) abundance has declined substantially in Suisun Bay even though populations have occasionally rebounded to high levels (Figure 8).

B-000305

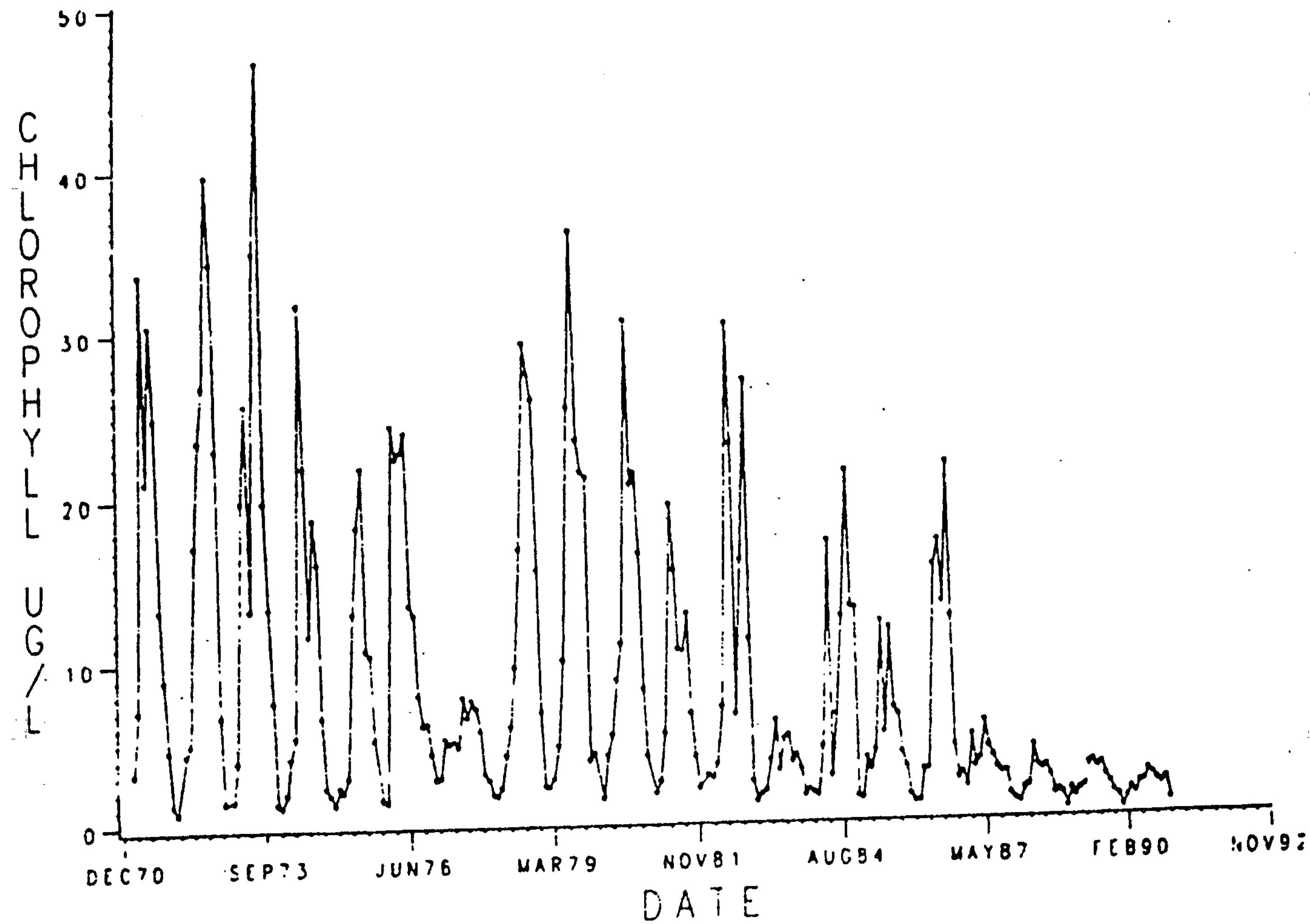


Figure 4. Chlorophyll Concentration in Suisun Bay, 1971-1990
(Figure from DWR report to State Water Resources Control Board)

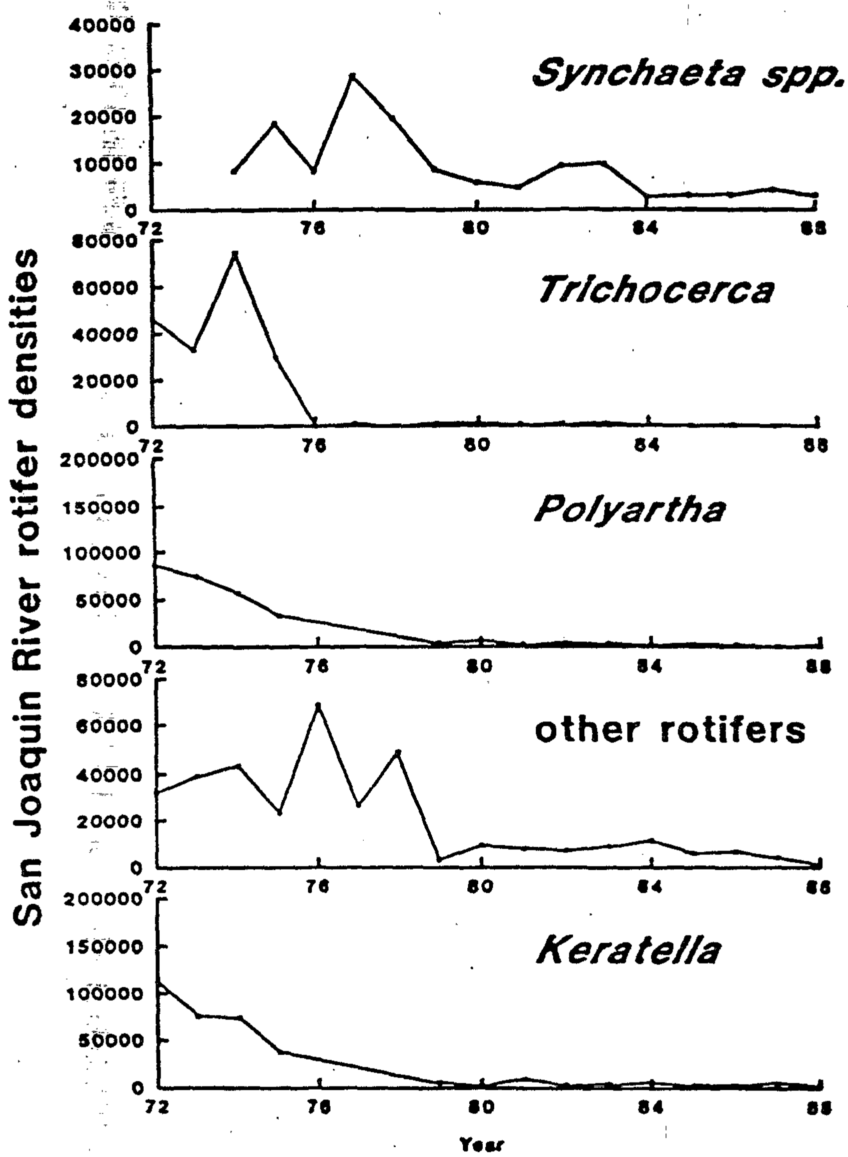


Figure 5 Mean densities per m³ of the abundant species of rotifers by year in the San Joaquin River
(Figure from Herbold et al. 1992)

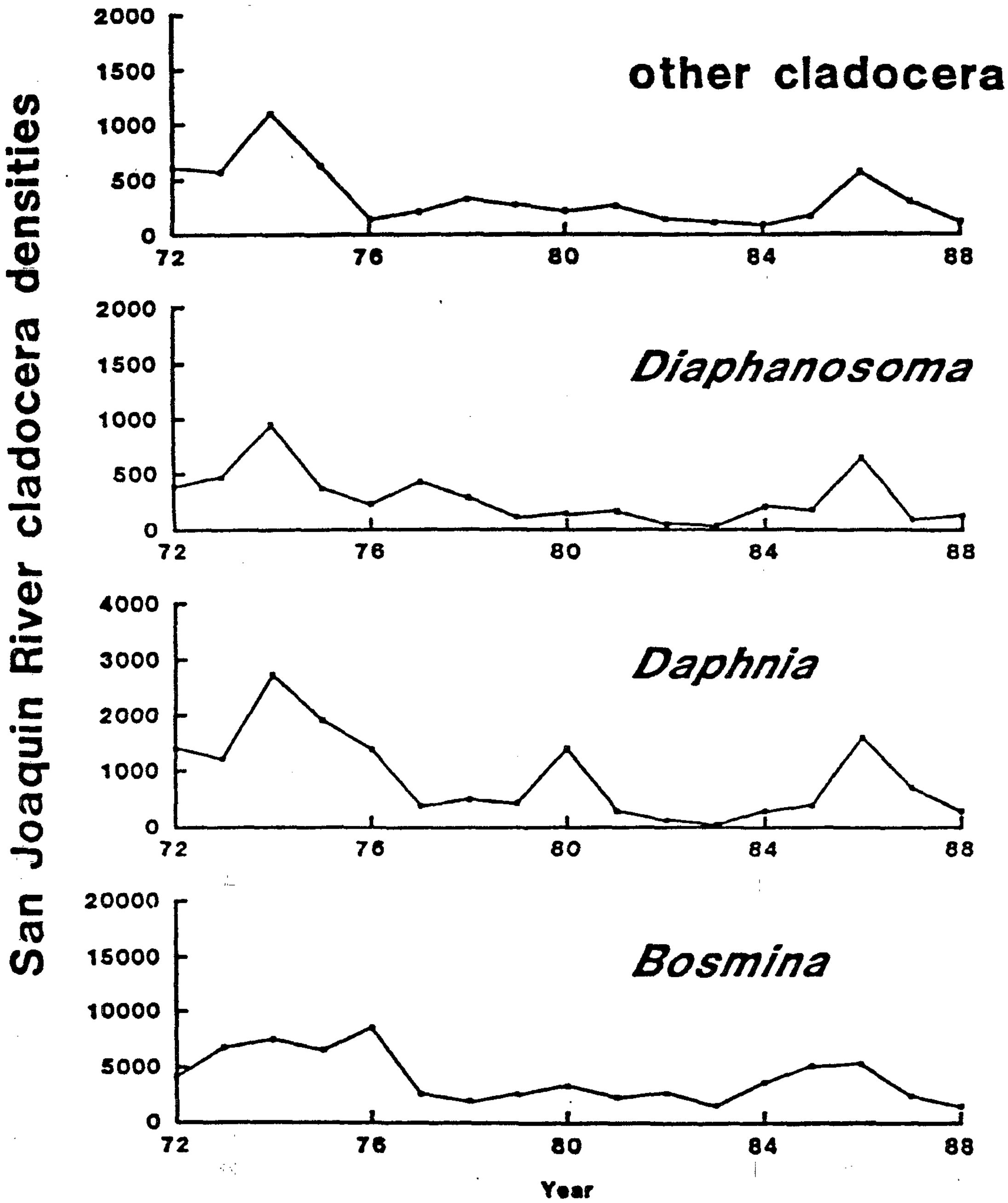


Figure 6 Mean densities of the three most abundant species of cladocerans in the San Joaquin River (no./ per cubic meter).
(Figure from Herbold et al, 1992)

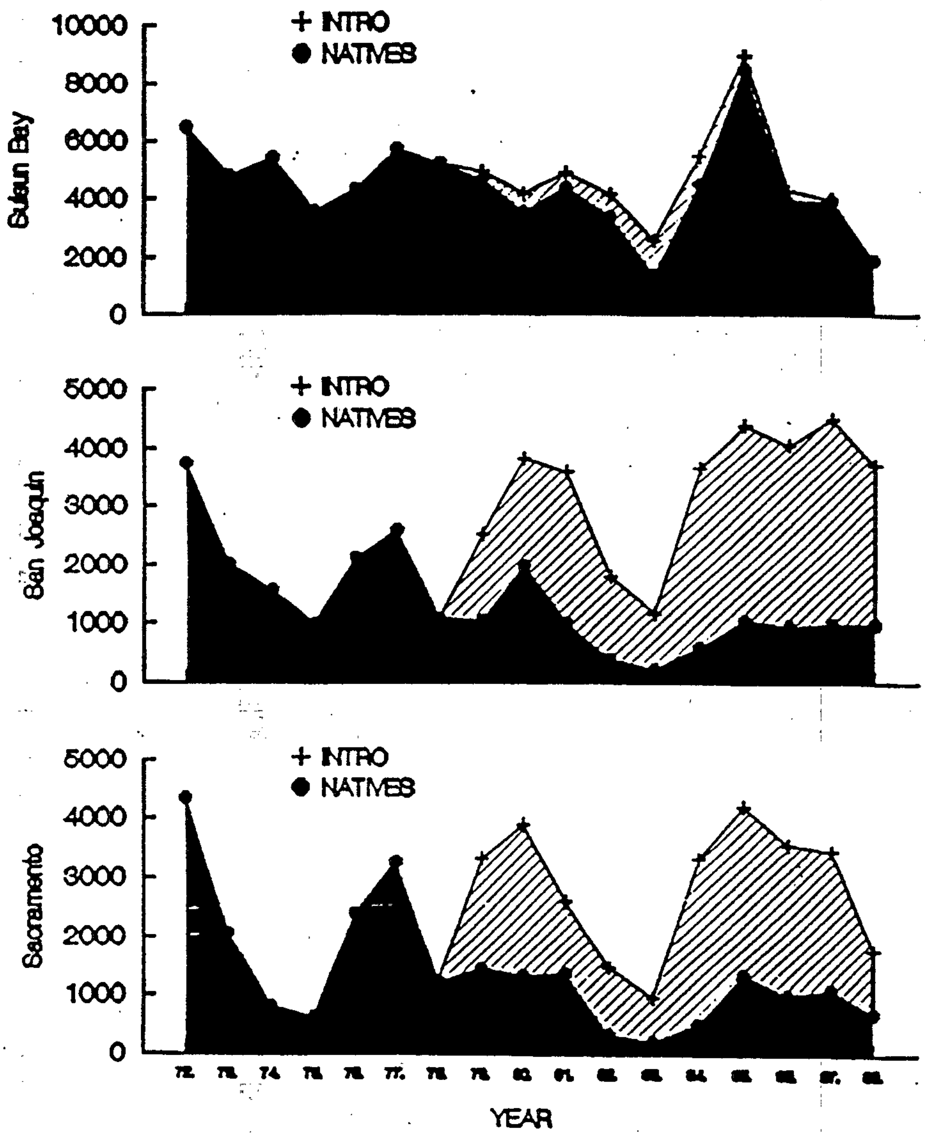


Figure 7 Comparison of densities (mean number per cubic meter) of native and introduced copepods in three areas: Sacramento River, San Joaquin River, and Suisun Bay

(Figure from Herbold et al, 1992)

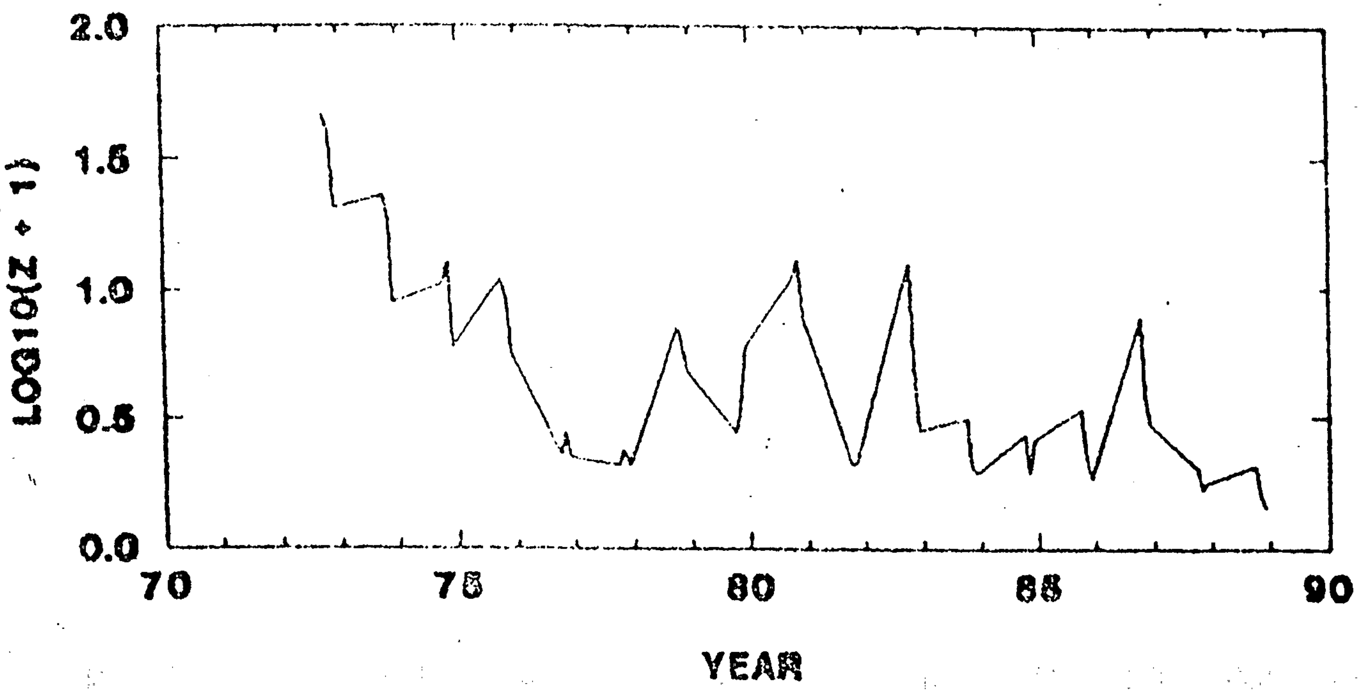


Figure 8. Neomysis Abundance (Figure from Obrebski et al, 1992)

BENTHOS

Benthic organisms (benthos) are animals that live in or on the bottom of the Estuary. Some burrow into the bottom sediments, while others live on the sediment surface. Most benthic organisms feed by straining phytoplankton and non-living organic matter (detritus) from the water column.

With few exceptions, all of the common benthic species now found in the Estuary have been introduced: accidentally or intentionally. Some species, like the Japanese littleneck clam and the soft-shelled clam, support sport fisheries.

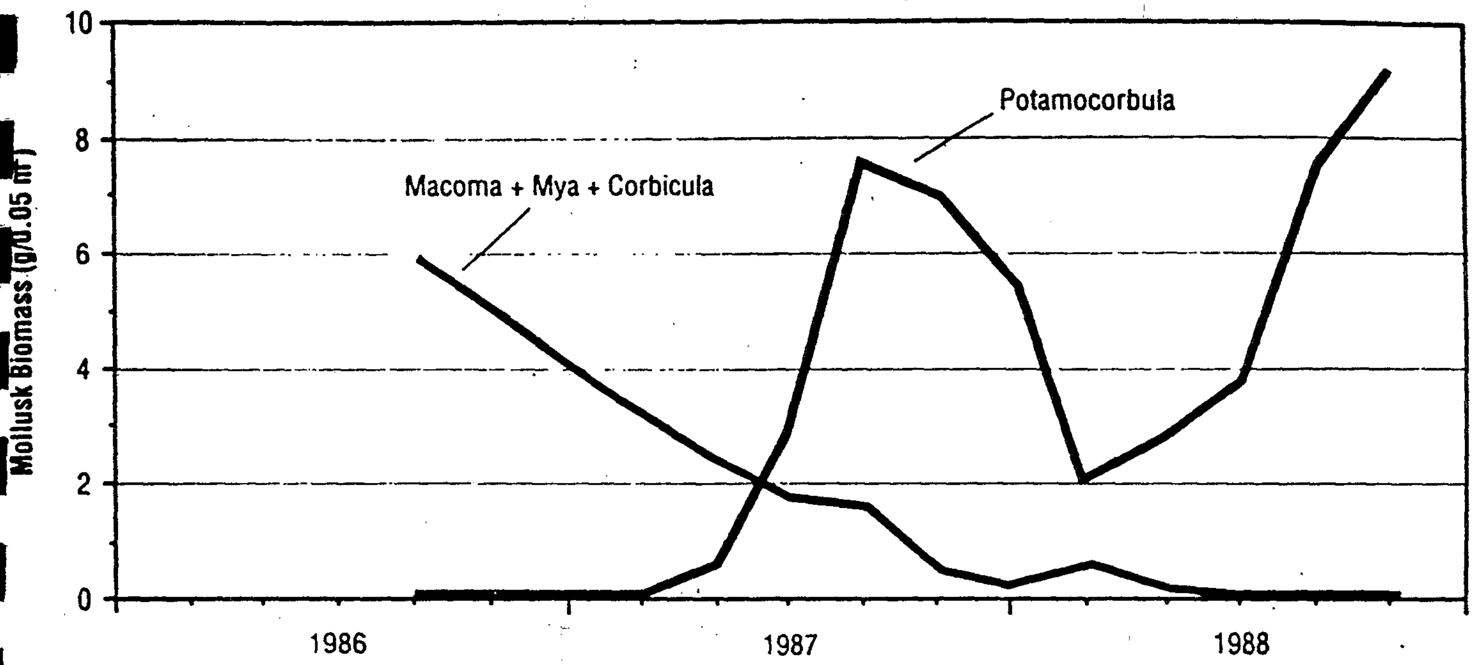
In the northern reach of the Estuary, the abundance and distribution of benthic species is greatly affected by salinity variation. Generally, during high outflow years, some brackish species (preferring moderately salty water) decline; during low flow years, species preferring salty water increase. In 1987, however, this pattern did not hold true. Following several years of very low flow and high salinity, the expected colonization of Suisun Bay by the brackish water species did not occur. Instead, a recently introduced clam (Potamocorbula amurensis) increased remarkably in abundance (Figure 9). The impact of this filter-feeding organism on phytoplankton has been dramatic and the fate of this non-native species when increased freshwater flows return to the system remains to be seen.

SELECTED FRESHWATER, MARINE AND ESTUARINE DEPENDENT SPECIES

Over 200 species of fish, shrimp, and crabs are known to inhabit the Estuary; each has unique life processes and utilizes the Bay-Delta system differently.

Figure 9. (From Monroe and Kelly, 1992)

Biomass of* Potamocorbula *and Other Mollusks in Grizzly Bay, 1986-1988



Bruce Herbold, Alan Jasby, and Peter Moyle, in their "Status and Trends Report on Aquatic Resources in the San Francisco Estuary," describe the Bay community this way:

> "Marine species can primarily be divided into those which are seasonally present and those which maintain at least part of their population in San Francisco Bay year-round. Probably because of their large populations in the ocean, seasonal species comprise many of the most abundant fishes to be found in the bay...[still] catches of [ocean] species are seasonal and regularly fall to less than a hundredth of their peaks...[Some species spawn in the Bay, while] other seasonal species spawn offshore and rely on density-driven bottom currents, augmented by tidal forces, to carry their offspring in the bay...Species that rely on bottom currents for transport should be adversely affected by low river outflow because low outflow cannot provide the density stratification necessary to propel ocean water into the Bay.
>
> Resident marine species often fluctuate in their abundance in the Bay from year to year, apparently in response to the distribution of marine waters. Most of these species are benthic..."

Estuarine species are those whose spawning can occur in marine or freshwater, but brackish water habitats provide critical nursery areas. Thus the bay can also act as a migration corridor for some species. Freshwater fish are those that spend their entire life in freshwater habitats. Marine species spend their lives predominately in salt water habitats.

What follows is a presentation of some data and trends that have been developed for particular species.

1. White Catfish

White catfish are a non-native species introduced into the Sacramento-San Joaquin Delta in 1874. Conditions were apparently favorable and their abundance rapidly increased, leading to a commercial fishery until outlawed by the State Legislature in 1953. White catfish has become an important sportfishery in recent years.

Population estimates of adult white catfish have not been made since a 1978-1980 study. However, data from three independent sources (sampling during striped bass surveys, fall surveys and salvage at the State and Federal fish screens) indicate that abundance of white catfish has declined severely since the mid-1970's (Figure 10). Available evidence indicates catfish reproduction has been concentrated in the south and east Delta, and that this source of recruitment of new fish to the overall catfish population has greatly diminished since the early 1970's.

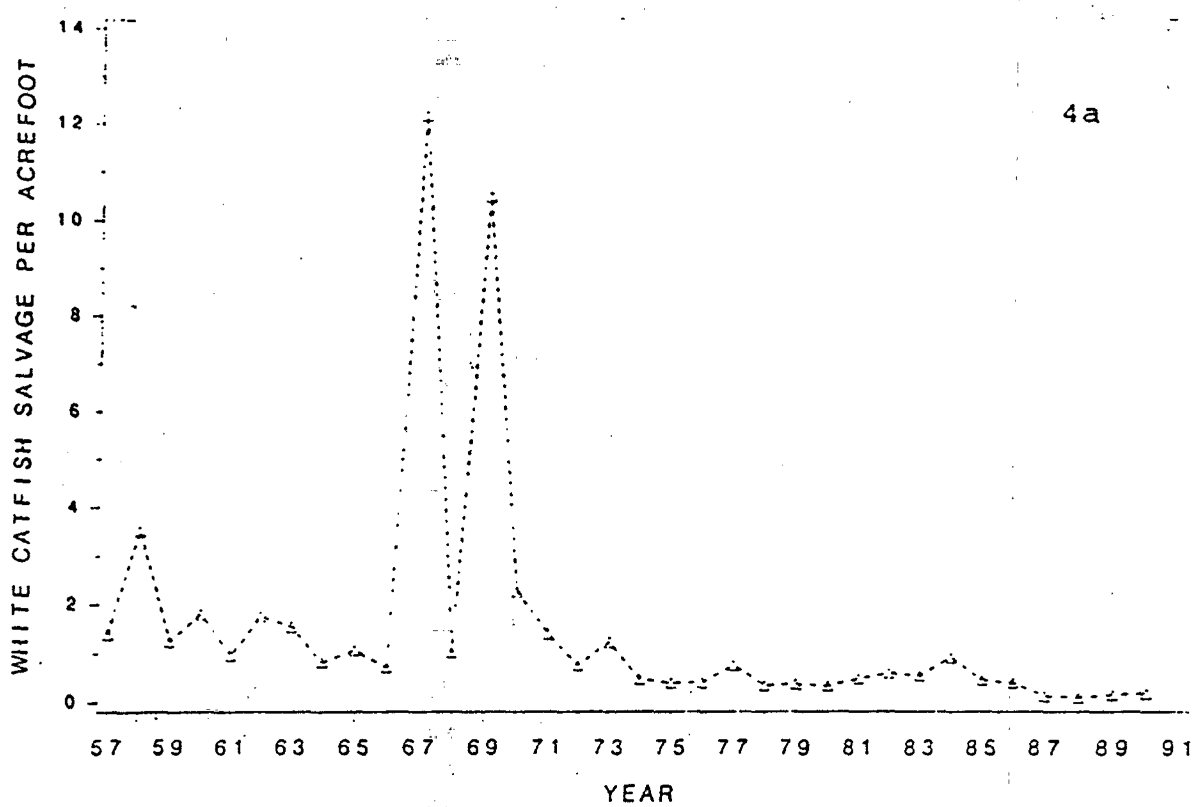
2. Delta Smelt

The delta smelt is a small, slender-bodied fish, with a typical adult size of 2-3 inches, although some may reach lengths of up to 5 inches. They are fast growing, short-lived, and feed entirely upon zooplankton. Food studies indicate that the diet of smelt larvae (just hatched fish) consists of small copepods and, as they grow, larger copepods. Delta smelt spawn in freshwater or in slightly brackish water.

Delta smelt are only found in this Estuary, and have been collected as far up the Sacramento River as the mouth of the American River, and at Mossdale on the San Joaquin River. Their normal downstream limit appears to be western Suisun Bay, although during episodes of high Delta outflow they can be washed into San Pablo and San Francisco Bays.

Various types of surveys have charted the abundance of delta smelt since about 1959, and information from seven of these independent data sets has demonstrated a dramatic decline of the Delta smelt population, with particularly low levels recorded since 1983 (Figure 11).

Notably, the abundance index based on fall sampling, which provides the best measure of population trends, has declined from values between 1,000 to 1,500 between 1970 and 1974 to values in the 300-400 range in the late 1980's and early 1990's. The other indices used to measure abundance remained consistently low during this entire period as well.



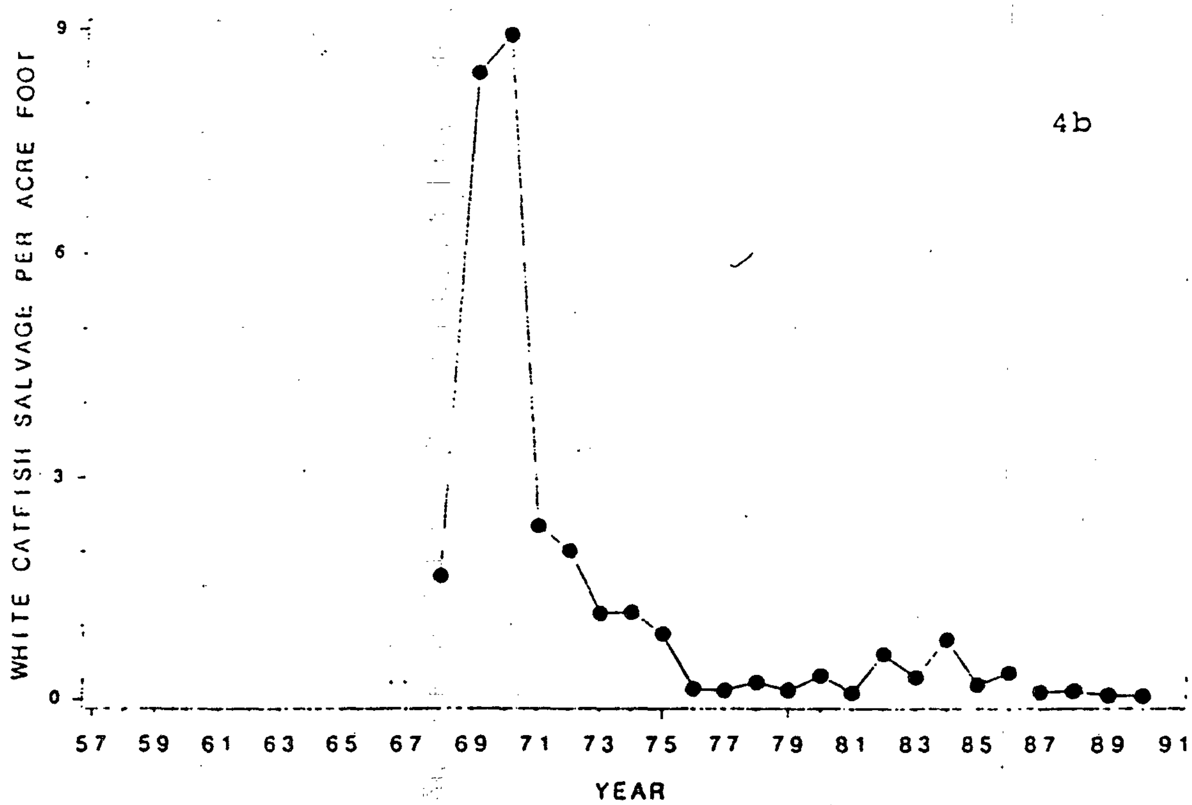


Figure 10. White catfish salvage per acre foot of water exported during summer (June through September) for the CVP fish screen facility (4a) and for the SWP fish screen facility (4b).

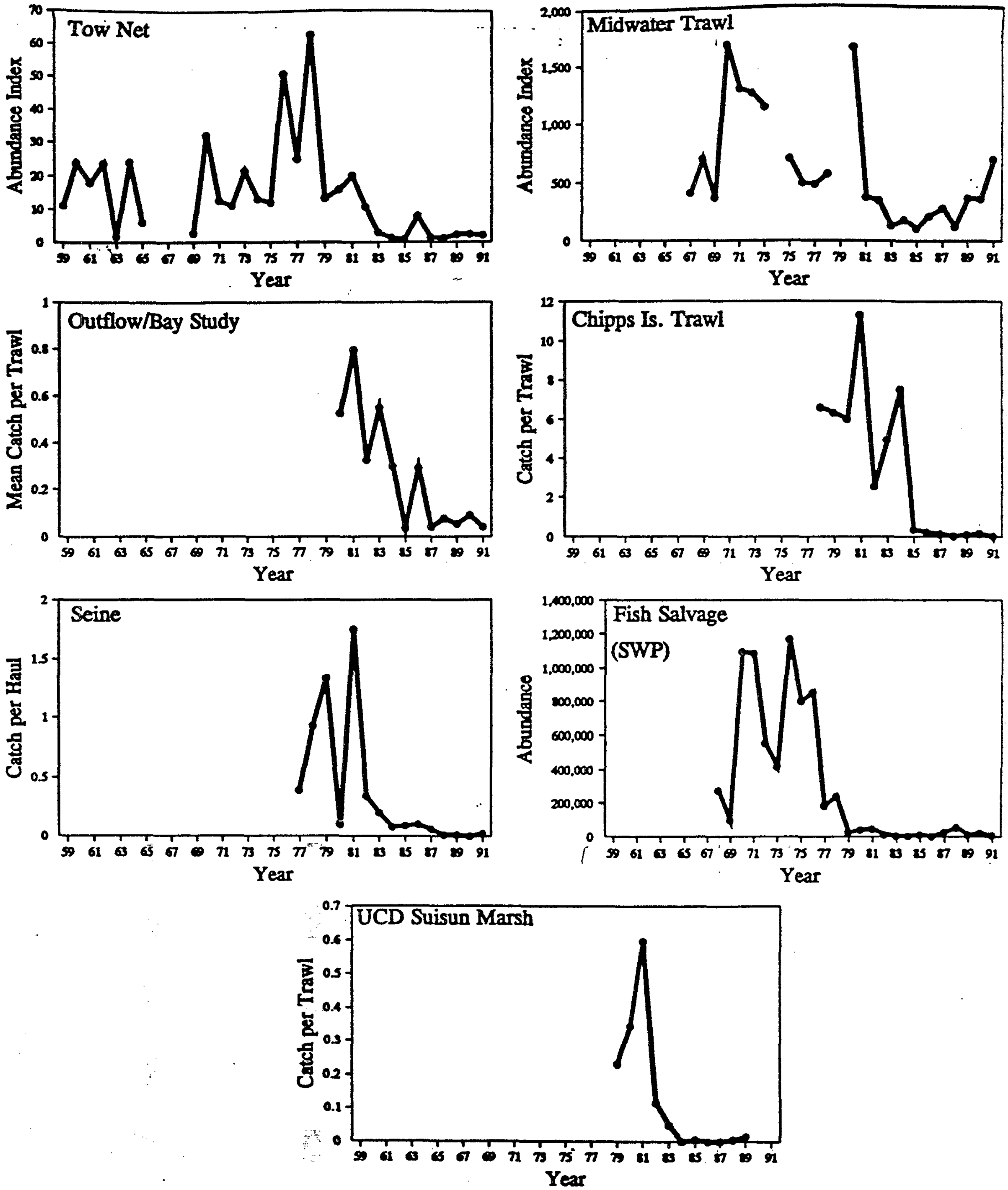


Figure 11. Trends in delta smelt as indexed by seven independent surveys (updated from Stevens, et.al., 1990, Figure 4).

As to 1992 population levels, the abundance index for September was 71.5, down from 126 in September 1991. The October index was 3.5 which represents a total of 2 smelt captured! This is the lowest index ever for October and the second lowest index for any month. It is felt that for some reason the sample program missed the population. For all of 1992, the index was 157 which represents one of the lowest indices on record.

The geographic distribution of delta smelt is also of interest. Historically, when populations were at higher levels, Delta smelt were distributed throughout the Estuary because suitable habitat was more widely available. Recently, however, the population has become heavily concentrated in the lower Sacramento River, between Collinsville and Rio Vista. Looking at the decline by geographical areas, it is apparent that it began earlier in the south and east Delta then in the rest of the Estuary. This geographical impact is consistent with the decline observed in white catfish abundance.

Alarm over the observed declines of Delta smelt prompted the U.S. Fish and Wildlife Service (USFWS) to list it on the Threatened and Endangered Species list in March, 1993 and recently the California Fish and Game Commission listed it as threatened under the California Endangered Species Act.

3. <u>Longfin Smelt</u>

Longfin smelt are found in fresh, brackish and marine waters from San Francisco Bay to Prince William Sound in Alaska. In California, they occur in numerous rivers, estuaries and bays between the Oregon border and San Francisco Bay. These fish spawn in the lower Sacramento and San Joaquin Rivers, the Delta and the freshwater portions of Suisun Bay. During their second year of life, they inhabit most of the Bay and occasionally venture into the Gulf of the Farallones. In most years, the entire life cycle of longfin smelt is carried out in the Estuary. Larvae, juveniles, and adults are eaten by predatory fish, birds, and marine mammals, and are an important component of the estuarine food chain.

The most accurate index of longfin smelt abundance in the Estuary comes from a fall sampling program which began in 1967. Since 1967, the longfin smelt abundance index has fluctuated widely from year to year (Figure 12). Since 1982, when the index was 62,929, values have dropped precipitously until the 1992 level of approximately 73 was reached. A characteristic of the fluctuations in longfin smelt abundance is that they are closely correlated with freshwater flows between February and May. No similar relationship exists for Delta smelt.

The reduction in longfin smelt abundance has prompted parties to petition the U.S.F.W.S. to list this fish under the Endangered Species Act as well.

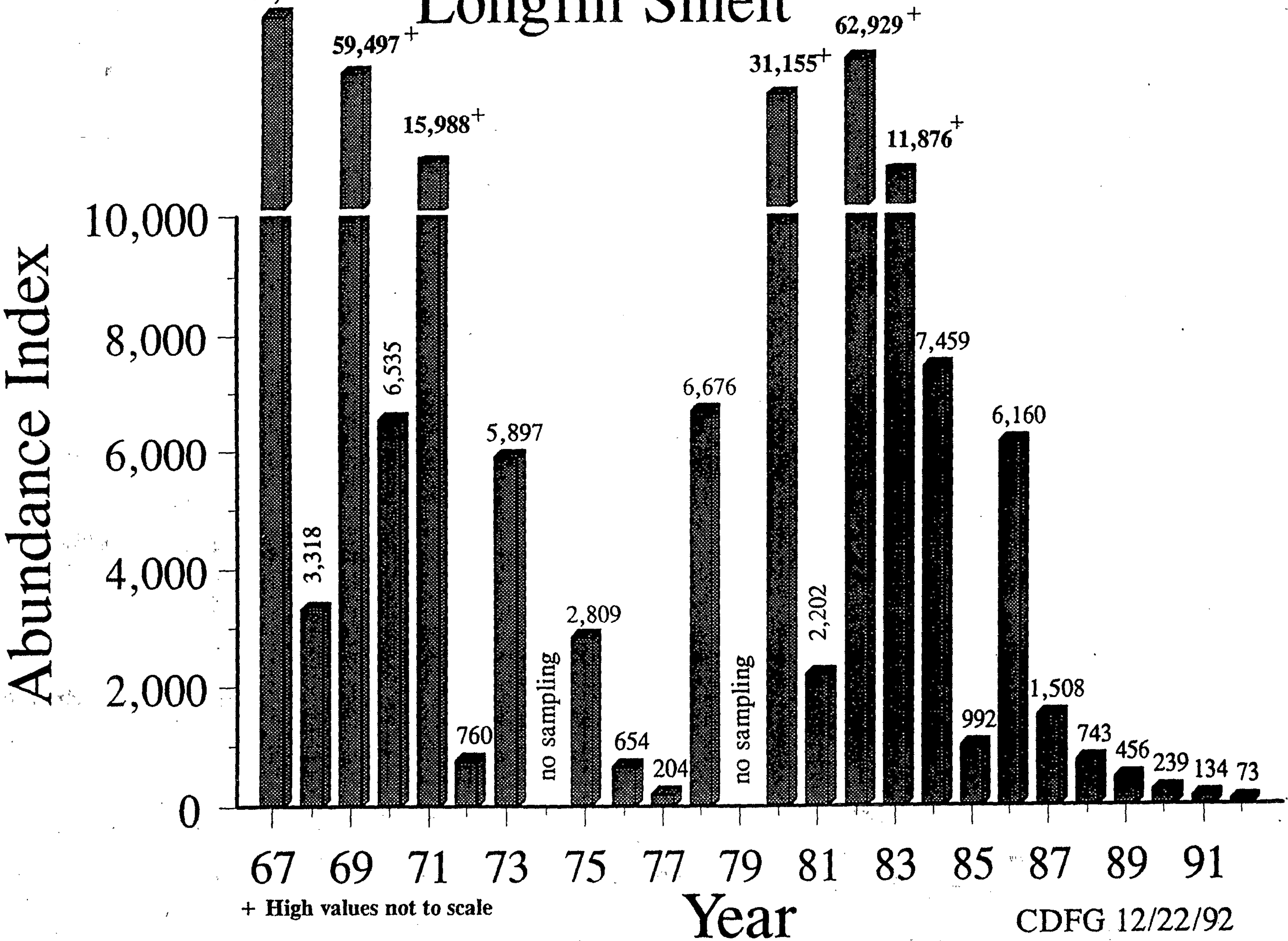
4. <u>Sacramento Splittail</u>

The splittail is a large minnow endemic to the Estuary. They are relatively long lived fish, reaching over 14 inches in length by their fifth year. Although considered a freshwater species, adults and sub-adults have an unusually high salt tolerance.

The loss of spawning and nursery habitat as a result of reclamation activities has significantly impacted the splittail population. Historically, the splittail could be found in low elevation waters of the Central Valley, from Redding to Fresno. Currently, their abundance and distribution is much more limited. They are now only found in the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun and Napa marshes, and tributaries of north San Pablo Bay.

Abundance indices of splittail have varied over the years. They were relatively high in the late 1960's and then declined severely until 1977. From 1977, abundances increased until an all time high was reached in 1983. After that period the indices again decreased to 3.6 in 1992. (Table 1)

Fall Midwater Trawl Abundance Index
Longfin Smelt



+ High values not to scale

CDFG 12/22/92

Figure 12

Table 1. Splittail Indices of Abundances for 1967 to 1992 Based on Midwater Trawl Catches.

Year	Index	Year	Index	Year	Index
1967	66.3	1977	0.0	1987	28.6
1968	18.1	1978	37.2	1988	9.0
1969	19.4	1979		1989	4.1
1970	25.4	1980	17.0	1990	9.0
1971	17.4	1981	18.3	1991	17.9
1972	12.5	1982	118.6	1992	3.6
1973	4.4	1983	153.2		
1974		1984	16.2		
1975	3.6	1985	14.9		
1976	0.7	1986	57.7		

Because of their reduced abundance, Sacramento splittail are considered a species of special concern by the California Department of Fish and Game (DFG) and a petition has been submitted to USFWS to list them under the Federal Endangered Species Act.

5. Sturgeon

White sturgeon is a native anadromous (spawn in fresh water, migrate to ocean for adult stage) fish in the Estuary and the object of an important and growing sport fishery. Another native species, the green sturgeon, is much less common in the Estuary and legal-sized fish are seldom caught. White sturgeon make less extensive ocean migrations than green sturgeon and spend most of their life in the river and estuarine environment. These fish are long-lived and late-maturing. Their longevity allows them to reach a large size, reportedly as large as 1,300 pounds at over 100 years of age.

Sturgeon spawn in both the Sacramento and San Joaquin Rivers, but studies indicate more white sturgeon breed in the Sacramento River than in the San Joaquin. Increasing freshwater flows appear to trigger spawning. Larval movement and dispersal is also dependant on river flow, thus, the location of the nursery area of young fish appears to move farther downstream as flows increase.

Historical accounts indicate that a commercial fishery greatly reduced the estuarine white sturgeon population in the late 1800's. As a result, all sturgeon fishing was prohibited in 1917. The fishery was reopened to sport angling in 1954.

White sturgeon life history and population dynamics have been studied intermittently since the sport fishery reopened. Abundance estimates have varied substantially during that time (Table 2), which may be related to imprecision in the estimation process.

Table 2. Abundance Estimates of White and Green Sturgeon Greater than 102 cm in Length.

Year	White	White:Green	Green
1954	11,200	56.5	198
1967	114,700	62.0	1,850
1968	40,000	38.6	1,036
1974	20,700	101.9	203
1979	74,500	52.6	1,416
1984	128,300	106.3	1,207
1985	96,200	127.3	756
1987	84,000	163.7	513
1990	26,800	49.7	539

6. Pacific Herring

Pacific herring support a large fishery in the Bay. The spawning population has been relatively stable with the largest variation associated with the El Nino condition of the 1976-1977 drought (Table 3).

7. Starry Flounder

Starry flounder are native to San Francisco Bay. They range from Santa Barbara northward to arctic Alaska, then southwest to the Sea of Japan. Starry flounder adults inhabit shallow coastal marine water, whereas juveniles appear to be estuarine-dependent and seek out fresh to brackish water areas of bays and estuaries for nursery purposes.

Starry flounder are a moderately important part of the sport fishery in California. As a result, the longest historical record of starry flounder numbers in San Francisco Bay comes from the sport fishery logs. Most of the starry flounder catch has occurred in San Pablo and Suisun Bays, but only catch data for San Pablo Bay is provided here (Figure 13). This information suggests that the fishery has declined in the Bay since the early to mid 1970's.

A more recent data base, using a biological sampling program, has also demonstrated declines in abundance indices starting in 1983 (Figure 14). Although abundance fluctuated upward somewhat in 1990 and 1991, overall abundance has been consistently low since 1986. Such continued low indices indicate that recruitment to and/or survival of starry flounder in the Bay has been very poor for the past five years. The role of the recent drought in these declines is unknown.

TABLE 3 - Annual Spawning Biomass of Pacific Herring

from the Period 1974-1990

YEAR	Metric Tons
1974-75	27
1975-76	25
1976-77	22
1977-78	4
1978-79	33
1979-80	46
1980-81	65
1981-82	99
1982-83	59
1983-84	41
1984-85	47
1985-86	49
1986-87	57
1987-88	69
1988-89	66
1989-90	71

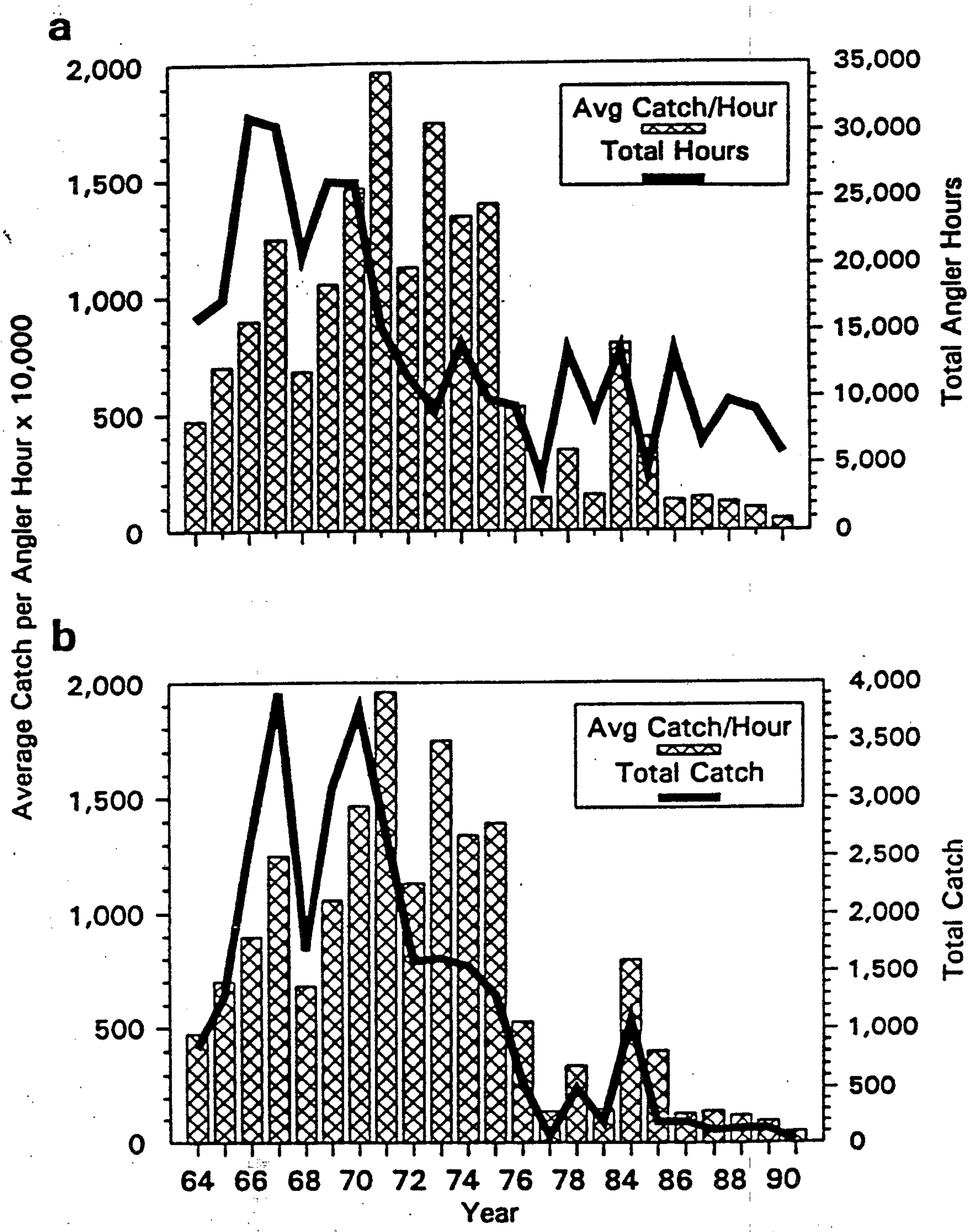


Figure 13. Starry flounder catch and fishing effort in San Pablo Bay based on Commercial Passenger Fishing Vessel log data from 1964-1990. A January through May period was use to calculate annual data. Data for the years 1979, and 1981-1983 were not available during analyses, nor were they plotted.

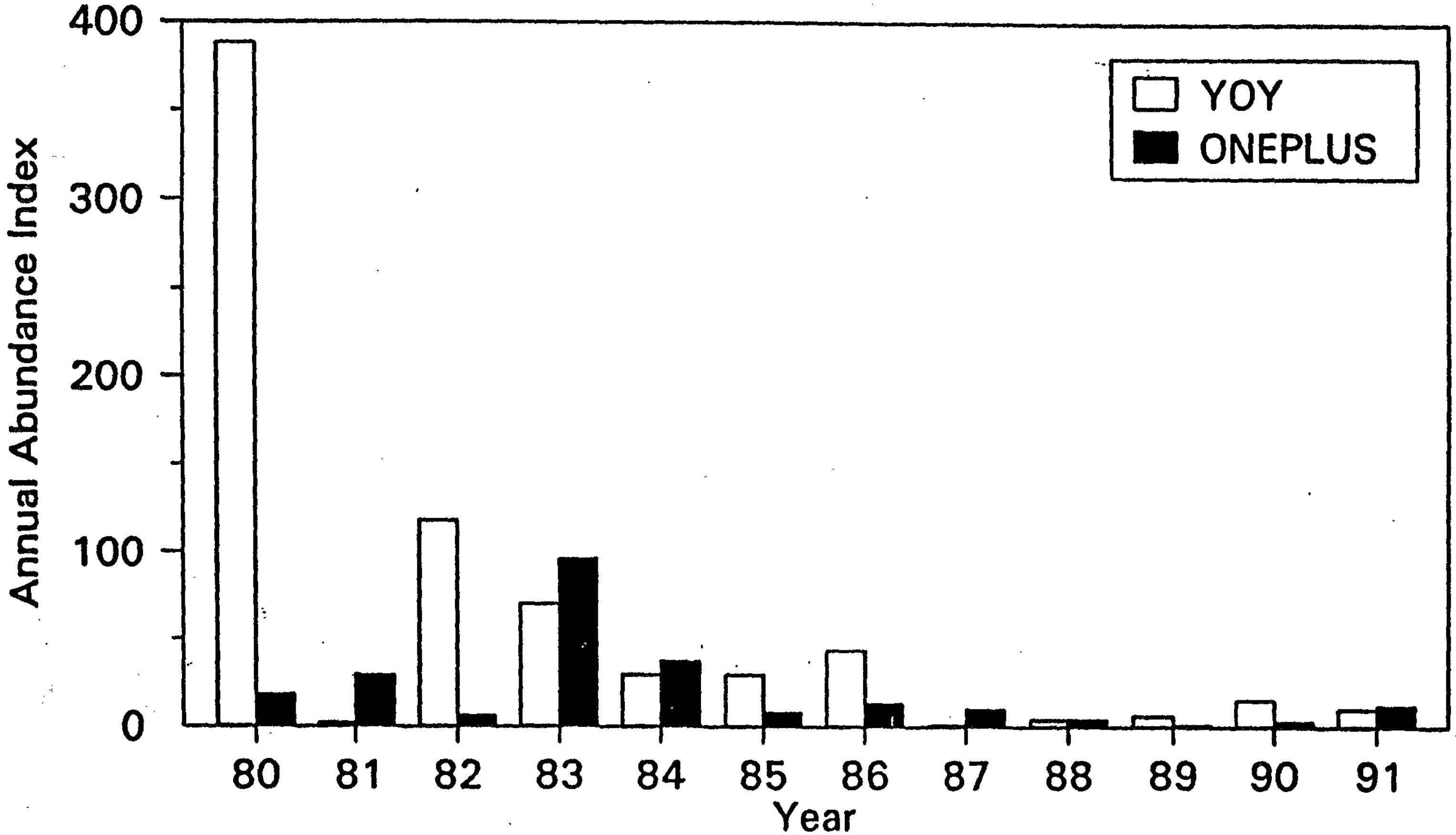


Figure 14. CDFG Bay Study starry flounder young of the year (YOY) and one year old (ONEPLUS) annual indices based upon otter trawl sampling from May through October and February through October for YOY and ONEPLUS fish, respectively. Data for 1989 represent sampling through August only for each age group. Data for 1991 are preliminary.

B — 0 0 0 3 2 6

8. Caridean Shrimp

Five species of Caridean shrimp are relatively abundant in the Bay: Crangon franciscorum, C. nigricauda, C. nigromaculata, Heptacarpus cristatus, and Palaemon macrodactylus. Heptacarpus and the three species of Crangon are native to the Estuary while Palaemon was accidentally introduced from the Orient in the 1950's.

Crangon ssp. are commonly referred to as "Bay shrimp" and Palaemon as "pile shrimp"; collectively they are often referred to as "grass shrimp". These species are fished commercially by trawl fishermen in the Bay and are primarily sold as bait. Earlier in this century, when there was a large market for dried shrimp, over three million pounds per year were landed (Figure 15). Since 1980 this fishery has landed between 100,000 and 200,000 pounds of shrimp per year. During the recent drought the fishery has concentrated in the Alviso Slough and Redwood Creek areas of the South Bay. Since 1985 shrimp fishermen have been prohibited from fishing in the area upstream of Carquinez Strait to protect juvenile striped bass. Occasionally, commercial fishermen are not able to meet demand because of a scarcity of large shrimp suitable for bait (Reilly, per. comm.).

Each of these shrimp species utilize the Bay as a nursery area to a varying degree. Timing of larval hatching and juvenile recruitment to the Bay is slightly different for each species, depending on geographic, temperature and salinity variables. Palaemon macrodactylus is unique in that it remains in the Bay throughout its life cycle. Adults are most common in Suisun Bay, the west Delta, and areas adjacent to freshwater sources such as the mouths of creeks in South San Francisco Bay and San Pablo Bay.

Aside from the commercial catch data mentioned above, dependable abundance indices for these shrimp species are only available since 1980 (Figure 16). The most important observation to note is that there has been a change in the species composition of the catch.

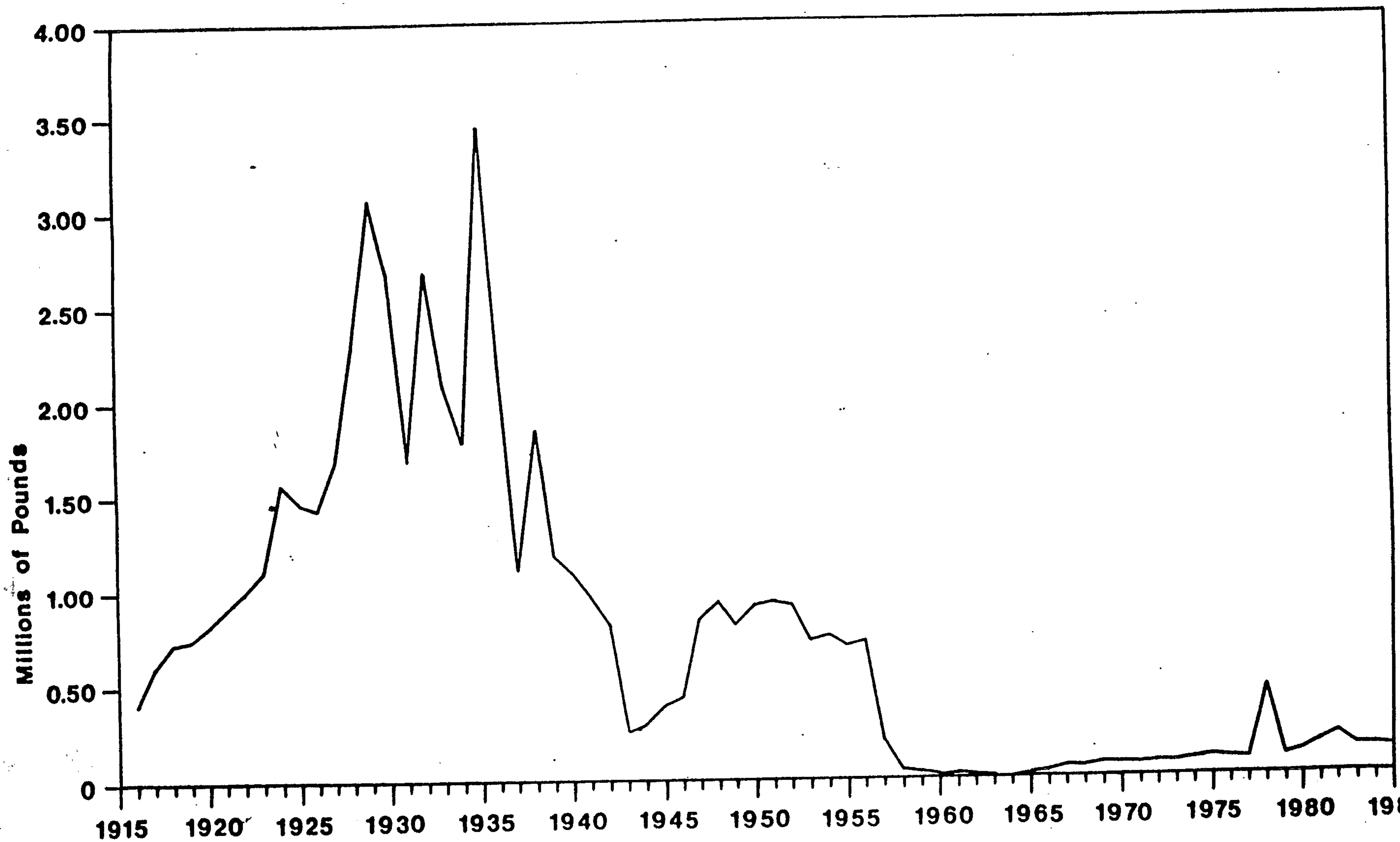
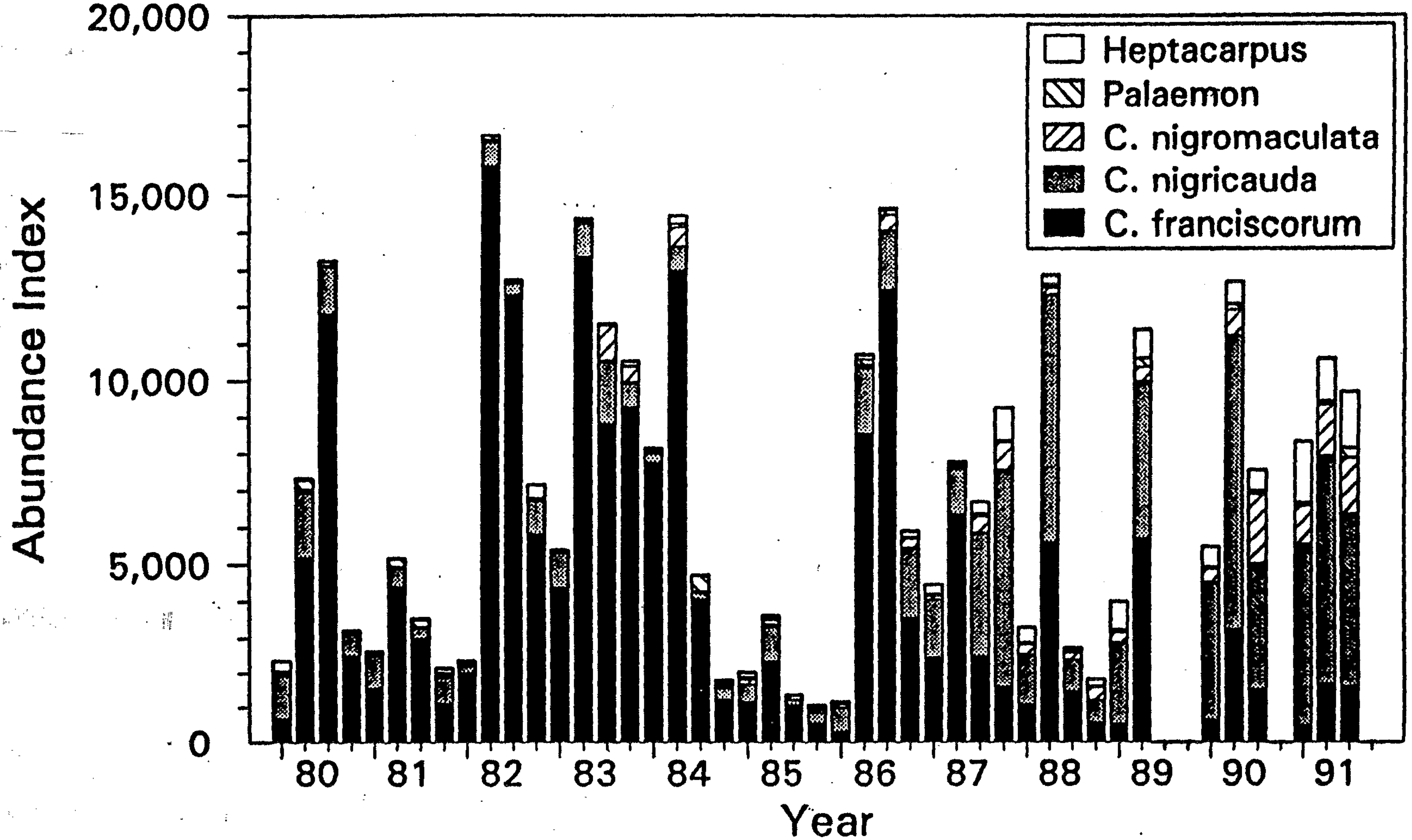


Figure 15. Commercial catch of bay shrimp in San Francisco Bay, 1916-1985.



30

Figure 16. Quarterly abundance indices for the five major species of shrimp in the Bay, 1980-1991. Quarters begin in February (February-April, May-July, August-October, November-January). There is no data for the third and fourth quarters of 1989 and the fourth quarter of 1990 and 1991.

In the early 1980's Crangon franciscorum dominated the catches, while in the late 80's and early 90's C. nigricauda, C. nigromaculata and Heptocarpus dominated. This change was caused by the differences in salinity preferences of the shrimp species and a series of dry, low outflow years. C. franciscorum is strongly related to the amount of freshwater outflow in the spring, while the other species do better in drier, low flow years.

Further information exists on the total biomass (weight of shrimp available for food sources in the ecosystem) during the 1980-1991 period. This information shows that the shrimp biomass during the 1988-1990 period was 20 percent less than the average biomass in 1981 and 1985 and 55 percent less than the average index for the remaining years. This is because most of the increase in numerical abundance in recent years was composed of smaller, immature C. nigricauda and C. nigromaculata rather than larger individuals.

9. Striped Bass

Striped bass are non-indigenous to the Bay-Delta. One hundred and thirty two small bass were introduced in 1879. Soon thereafter, striped bass were being caught in such large numbers that by 1889 they were being sold in San Francisco markets. In another 10 years the commercial net catch, alone, was averaging well over a million pounds annually. In 1935, however, all commercial fishing for striped bass was stopped in order to enhance the sport fishery.

Striped bass begin spawning in the spring when water temperatures reaches about 60 F. Most spawning occurs between 61 and 69 F and the spawning period usually extends from April to mid-June. "Stripers" spawn in freshwater where there is moderate to swift current.

The section of the San Joaquin River between Antioch Bridge and the mouth of Middle River, and two other channels in the same area, are important spawning grounds. The Sacramento River, between Sacramento and Colusa, is another important spawning area.

About one half to two thirds of the total striper eggs are spawned in the Sacramento River, and the remainder in the San Joaquin portions of the Delta. In wet years, some spawning occurs in the San Joaquin River above the Delta.

Striped bass are very prolific. A five pound female may spawn 180,000 eggs in one season and a 15 pound fish is capable of producing over a million eggs. This great reproduction potential, and favorable environmental conditions contributed to the striped bass establishing a large population within a few years after their introduction to the Estuary.

Abundance in the system probably reached a peak of 3 to 4.5 million fish. From the mid 1960's through 1976, the population was stable at 1.5 to 2 million fish. However, the population of legal-size striped bass in the Estuary has decreased substantially in recent years.

Because of the decline in bass abundance, recent research efforts have concentrated on factors which affect population size. Consequently, circumstances affecting survival of bass during their first year of life (when mortality is greatest) have been studied. Another phase of the striped bass research program is the development of reliable measures of adult population size and the number of young fish entering the fishery annually. Adult population estimates are made through extensive tagging of legal-sized stripers during their spring migration to the Delta from the ocean and/or Bay portions of the system.

Since the early 1960's when the annual recreational striper catch was relatively high, the catch has dropped to about 100,000-200,000 fish. Based on 1990 population estimates, the number of legal-sized adult striped bass fell to a record low of approximately 680,000 fish (Figure 17). Of these fish, approximately 90,000 were raised in hatcheries and stocked into the Estuary as yearlings two or more years earlier. Thus, the 1990 estimate for naturally produced fish is only about 590,000 fish. The abundance estimates of 1.2 million total striped bass and 960,000 naturally produced adult bass in 1991 are considerably greater than those for 1990.

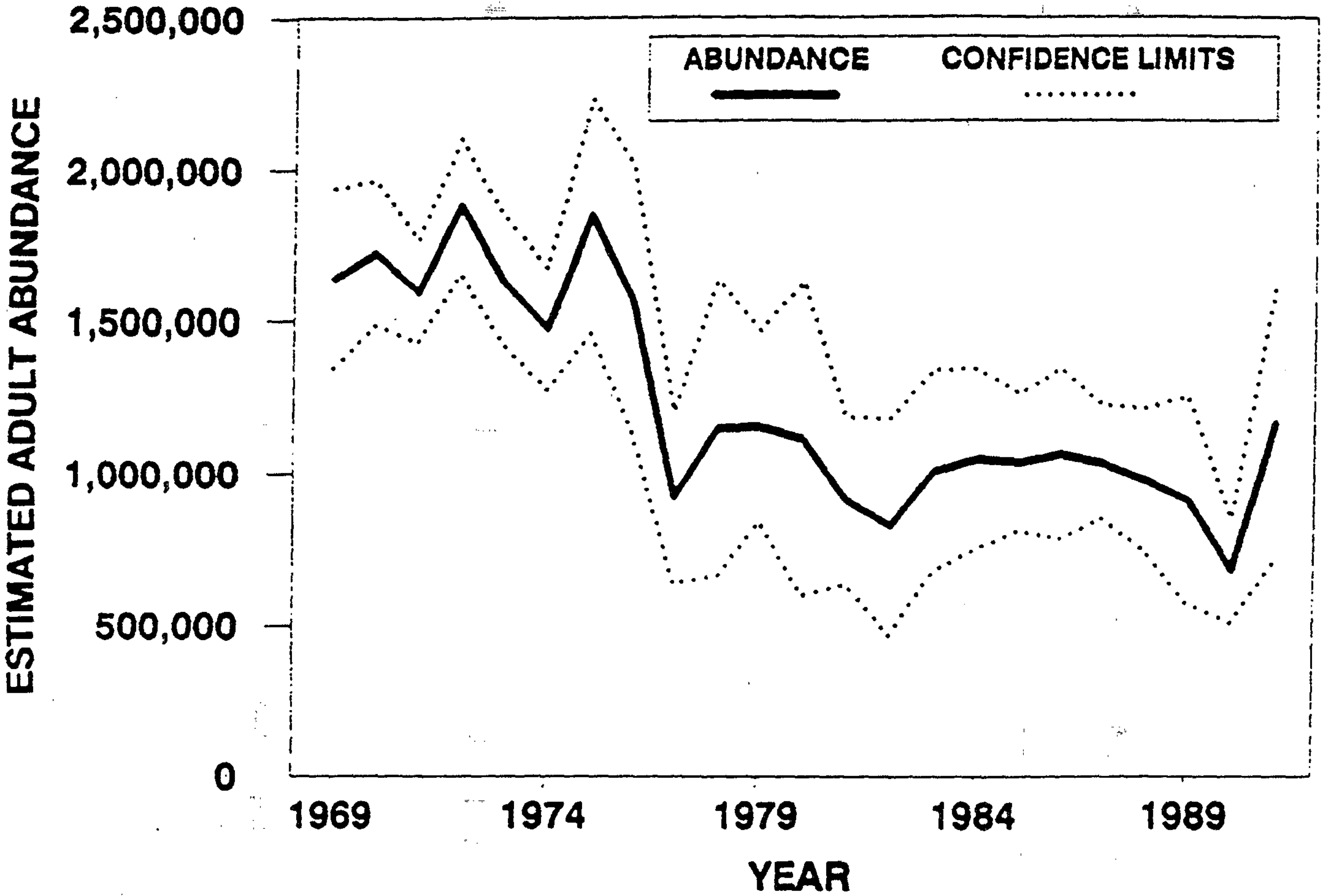


Figure 17. Trend in mark-recapture estimates of adult striped bass abundance in the Sacramento-San Joaquin Estuary, 1969-1991.

The 1991 estimates are not as reliable because the estimates for age 3 fish (the most numerous group) make up one-half of the total estimates and are based on an inadequate recapture sample of only two tags during the entire fall creel census. Due to recent concerns about predation on winter-run salmon, the hatchery propagaton program has been suspended.

The adult bass decline primarily reflects a decline in the number of new fish reaching legal-size. Estimates of the abundance of 3-year old fish, which are the youngest and most numerous component of the adult population, have been declining, and were at record lows in 1990. The lower recruitment of 3 year-old fish accounts for 76 percent of the adult bass decline and the remaining 24 percent of the decline is a result of changes in estimated survival of the adults themselves.

In addition to the decline in adult bass, there has also been an irregular but steady decline in production of young striped bass that extends back to the mid-1960's (Figure 18).

10. Chinook Salmon

Chinook salmon, also called king salmon, spawn in fresh water but spend most of their adult lives in the ocean. They are the largest of five species of salmon native to the Pacific coast of North America. Chinook salmon and steelhead rainbow trout are the principal salmonids using the Estuary. There are four distinct salmon runs in the Sacramento system that are named for the season of their upstream migration: spring, fall, late fall, and winter. Today, fall run are the principal run found in the Sacramento and the only run found in the San Joaquin drainage. About 80 percent of all four runs of the Central Valley chinook are produced in the Sacramento River basin. Typically, over 90 percent of all Central Valley spawners are fall run fish.

Spawning occurs where gravel size, porosity of the gravel bed, and water velocity enables the female to build a spawning redd (nest) and deposit eggs to be fertilized and covered.

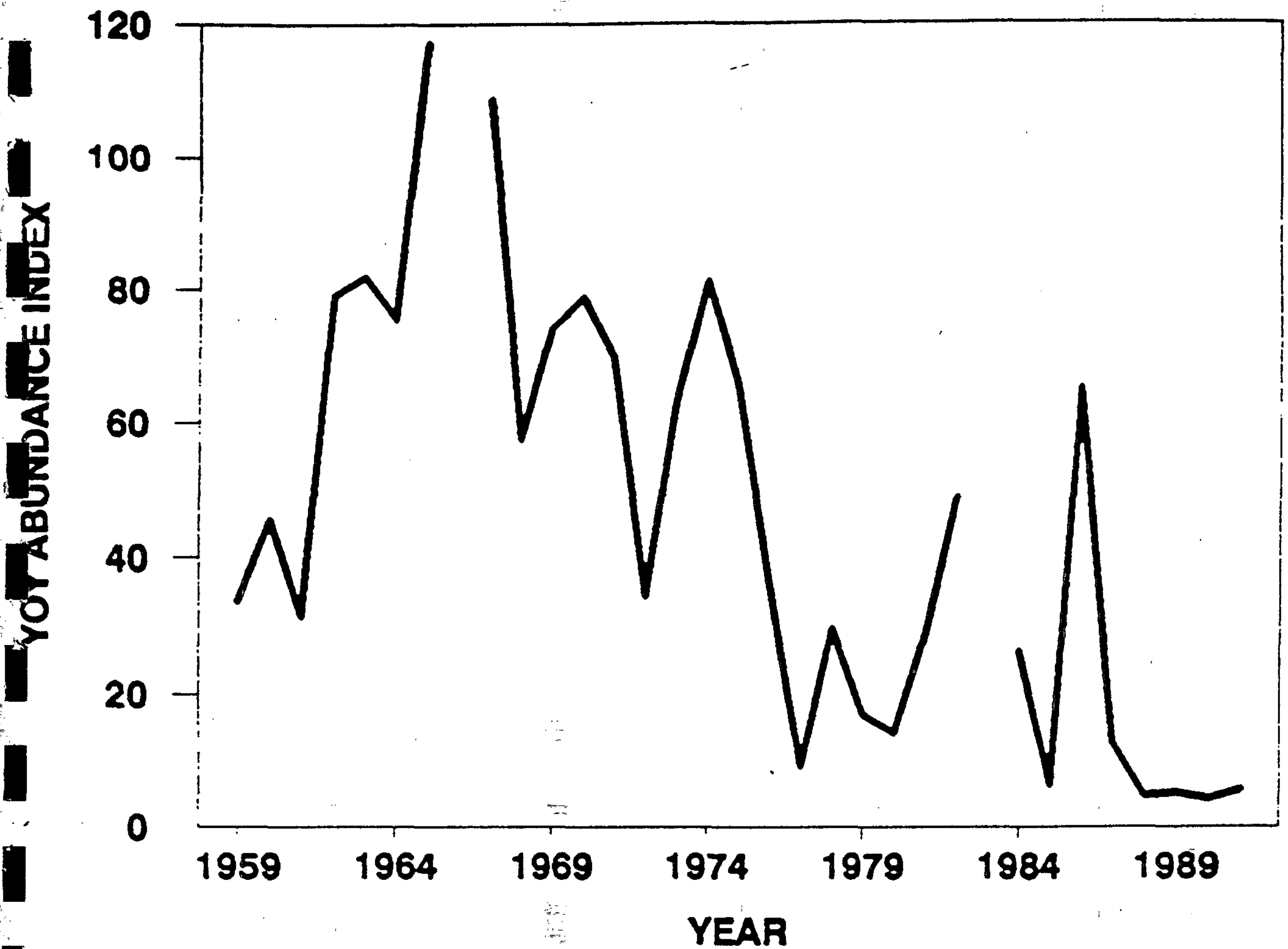


Figure 18. Trend in young striped bass abundance in the Sacramento-San Joaquin Estuary when mean length is 38 mm. Abundance index is based on catches of young bass during an annual tow net survey from 1959-1991.

Successful incubation of the eggs (50 to 60 days) requires flows which will remove waste products and silt, yet will not wash the eggs downstream. Temperature and dissolved oxygen conditions also affect hatching success.

The young salmon emerge from the gravel about 30 days after hatching. The young free-swimming "fry", initially about one and one-quarter inches long, rear for a few months in riverine or estuarine habitat, feeding on insects and zooplankton. Upon reaching about three inches in length, the fry undergo physiological changes, "smoltification", which enables them to survive the transition from fresh to salt water. These salmon are called smolts.

Smolts enter the ocean at various times of the year, depending on the run, to begin their growth to the adult stage. Central Valley chinook typically remain in the ocean from two to four years before they begin their return to freshwater to spawn and die.

Natural salmon populations have been augmented by hatchery production. Since the early 1970's, juvenile chinook salmon produced at the Feather River, Nimbus, and Mokelumne River hatcheries have been trucked and released downstream. Today, the fry produced at these hatcheries are released adjacent to Carquinez Strait. In contrast, salmon produced at Coleman National Fish Hatchery continue to be released in the upper Sacramento River.

The release of hatchery fish in the lower estuary has substantially increased survival and enabled a relatively strong ocean fishery to remain stocked despite reduced natural salmon populations. The success of the hatchery program, however, increases the risk of overharvesting natural stocks or Coleman fish that must through the Delta.

Monitoring of salmon in the Estuary is subdivided into various geographic regions: the Sacramento basin, the San Joaquin basin, and the Delta (other basins exist out of the Estuary drainage, i.e. Klamath basin and smaller coastal streams).

DFG, the USFWS, the U. S. Bureau of Reclamation (USBR) have all, over the years, counted salmon at various times and places in these basins. Some counts were made as early as 1937. Since 1953, DFG has made annual estimates of spawning fish on each of the major river systems. The counts include both young adult and adult fish from both natural and hatchery production. They are usually referred to as estimates of spawning "escapement" since they describe the numbers of chinook that have escaped the ocean fishery and returned to spawn.

Spawning runs of chinook salmon from all areas, since the regular counts started in 1953, have fluctuated greatly (Figure 19). In the last 20 years, the total runs have been averaging about 250,000 to 300,000 fish.

The remainder of this section will discuss population trends of the various salmon runs in the Sacramento and San Joaquin River Basins.

Sacramento River Basin:

An estimated 116,900 adult fall-run chinook salmon returned to the Sacramento River basin in 1991, about equal to the 1990 estimate of 107,300 fish, but 36 percent below the 10-year average of 171,500. The precipitous declines in salmon numbers in the Sacramento system are even more apparent when compared to prosperous years such as 1985 and 1986, when the spawning escapement estimates were 230,800 and 235,000 adults, respectively. Fewer than 40,000 fall-run fish were projected to make the run in 1992 (84 percent of 1991 and 45 percent of the 1982-91 average) (Figure 20). In 1992, DFG estimated that about 10,400 late fall-run salmon were present in the upper Sacramento River. The 1991 estimate for late fall-run was 8,600 (Figure 20).

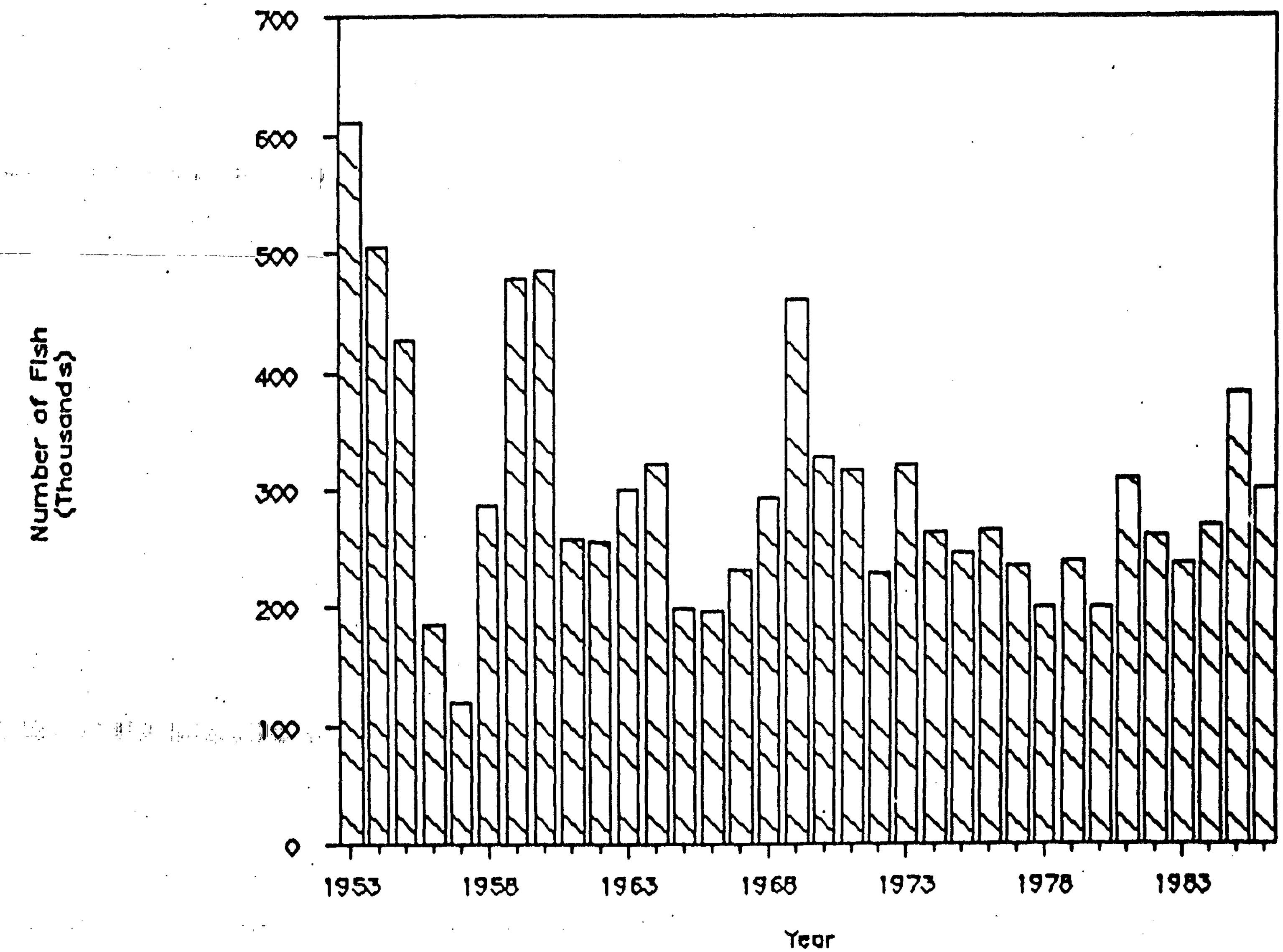
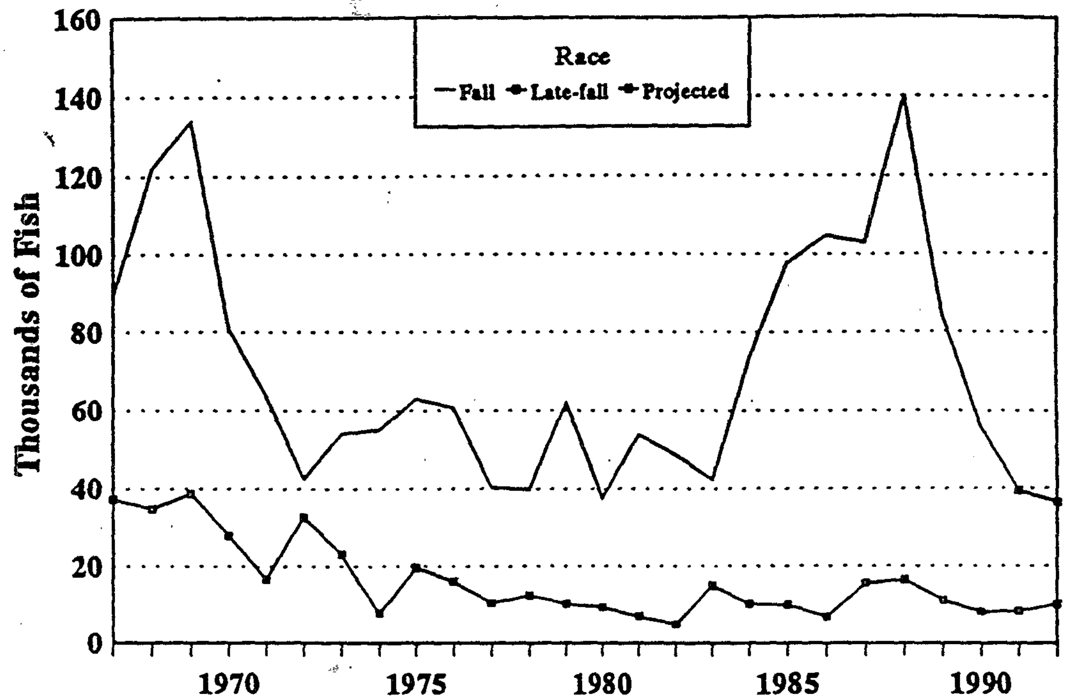


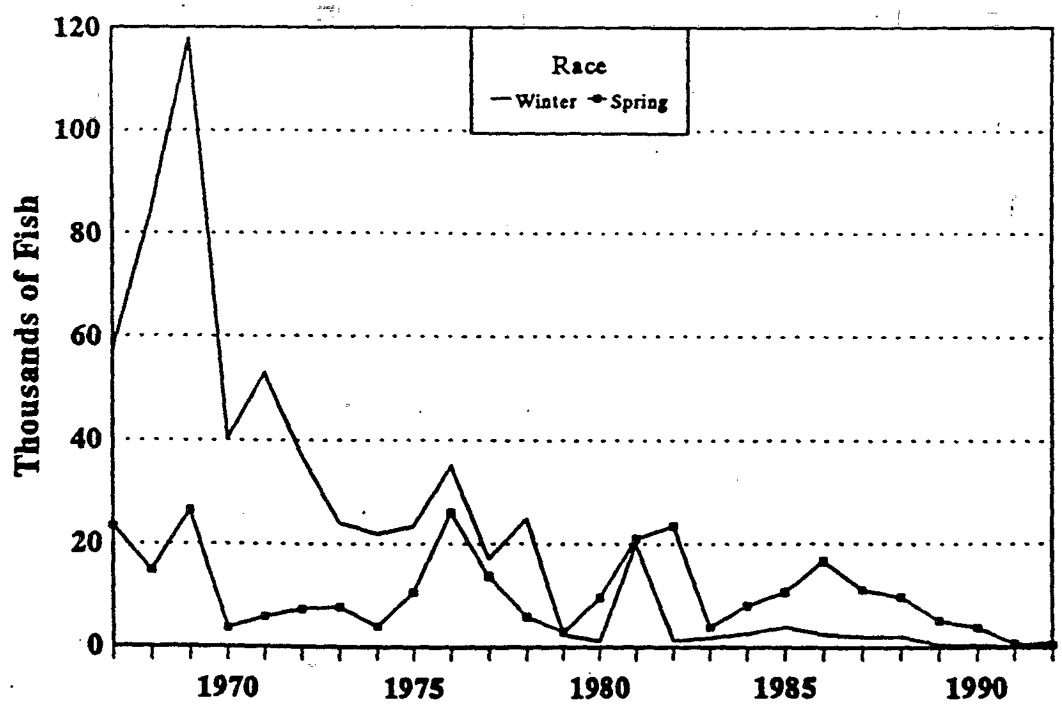
Figure 19. Total spawning escapement of Central Valley chinook salmon 1953-1987 (Taylor 1973, Reavis 1983, Pacific Fisheries Management Council 1984).

B-000337

FIGURE 20 RED BLUFF DIVERSION DAM FISH COUNTS
1967 through 1992
Fall and Late-fall Races



RED BLUFF DIVERSION DAM FISH COUNTS
1967 through 1992
Winter-run and Spring-run Races



DFG estimated that fewer than 500 spring-run fish used the Sacramento River above Red Bluff in 1992. This estimate replaces the 1991 estimates of about 800 spring-run chinook salmon as the lowest number ever recorded. In the late 1960's the spring-run numbered in the 20,000's.

Winter-run chinook salmon counts started when Red Bluff Diversion Dam was completed in 1967, and numbers have steadily declined from about 118,000 fish in 1969 to an estimated 1,200 fish that returned in the 1992 season. Even though the 1992 estimate is very low compared to the late 60's, it still represents a six-fold increase over 1991's estimates of about 200 fish. DFG expects low returns of winter-run for the next several years. As a result of these low numbers, the State Fish and Game Commission has listed this fish as endangered under California law, and the National Marine Fisheries Service (NMFS) has listed this fish as threatened under the Federal Endangered Species Act, triggering significant restoration efforts aimed at raising levels to more acceptable numbers. NMFS has also proposed the Sacramento River, Bay-Delta, and San Francisco Bay as critical habitat for winter-run salmon.

San Joaquin Basin:

Annual population surveys have been taken in the San Joaquin Basin since the early 1950's. During that time, the annual populations of salmon have experienced wide fluctuations (Figure 21). The 1991 counts of fall-run chinook salmon produced an estimate of about 1,100 fish, well below the 76,100 that returned in 1985. Of the total, about 500 returned to the Mokelumne River and the remaining 600 fish were scattered among the Stanislaus, Tuolumne, and Merced rivers - of which about 200 strayed into Mud Slough near Los Banos.

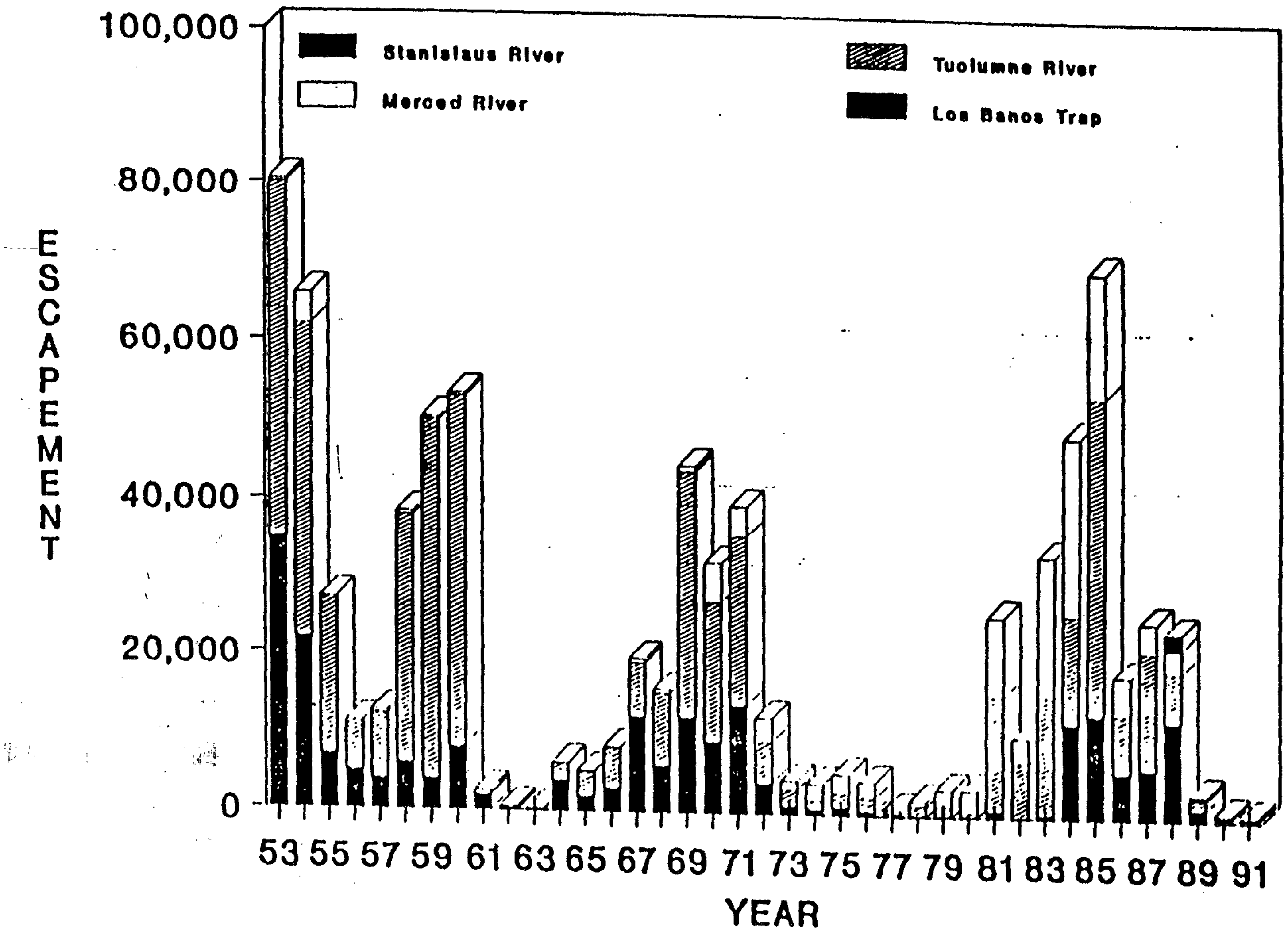


Figure 21. Recent Fall-Run Chinook Salmon Escapement in the San Joaquin Drainage

Summary--

Traditional indices of salmon populations suggest that most runs of chinook salmon in the Estuary and its watershed have declined significantly in recent years, with little evidence suggesting near-term improvement. Declining numbers for 1992/93 have already been documented for some runs in spite of additional restrictions imposed on commercial and sport fisheries both inland and in the ocean.

It should be noted that a few stream systems, such as the Feather and the America Rivers (Sacramento Basin), which are supported by an effective hatchery, have maintained sufficient populations of salmon through the 1991 season. In general, the average runs in these rivers have approximated or exceeded the abundance of salmon prior to the completion of Oroville and Folsom dams.